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PROCEEDINGS OF THE SOCIETY OF ARTS.

THIRTY-SEVENTH YEAR, 1898–99.

BOSTON, March 23, 1899.

THE 524th regular meeting of the SOCIETY OF ARTS was held this day at the Massachusetts Institute of Technology, with Professor George F. Swain in the chair. Sixty-eight persons were present.

The proceedings of the last meeting were read and approved. The Chairman then introduced Mr. Francis R. Hart, F. R. G. S., President of the Cartagena-Magdalena Railway in Colombia, Central America, who read a most interesting paper on "An American Railway in Colombia."[1] He described the great natural advantages of the port of Cartagena, and the richness of the country drained by the Magdalena River. This river is navigable for some seven hundred miles, and it furnishes a natural road over which the products of the interior may be transported. The Magdalena River flows within about sixty miles of the port of Cartagena, and as it has no good harbor at its mouth, a railway has been constructed between the river and the city by the company which operates the river steamboats.

The leading engineering feature has been the avoidance of high trestle bridges over the river beds by changes in the line to conform

[1] *Technology Quarterly*, June, 1899, pp. 123–134.

with the water divides, and the diversion of the smaller streams. Many interesting pictures were shown to illustrate the character of the country and buildings erected by the company.

A discussion followed. The meeting was then adjourned.

BOSTON, April 13, 1899.

The 525th regular meeting of the SOCIETY OF ARTS was held this day at the Massachusetts Institute of Technology with Mr. George W. Blodgett in the chair. Forty persons were present.

The proceedings of the last meeting were read and approved. Mr. Charles L. Norton, '93, Instructor in Heat Measurements at the Massachusetts Institute of Technology, and Mr. Osman S. Armstrong, Electrician, Riverside Press, Cambridge, were elected Associate Members of the Society.

The Chairman then introduced Mr. George L. Hosmer, of the Massachusetts Institute of Technology, who presented a paper on "The Middlesex Fells Geodetic Observatory."[1] This observatory is intended primarily to be used in giving instruction in the most refined methods of determining latitude and longitude, and secondarily to be used in magnetic and gravity observations. A description was given of the building and instruments, which include a transit of $2\frac{1}{2}$ inches aperture, 27 inches focus, a sidereal chronometer, chronograph, alt-azimuth, etc.

Observations have been made during the past term for the determination of time, and on latitude by Talcott's method. Arrangements have been made for the determination of longitude by telegraph connection with the Harvard observatory. The freedom of the observatory from vibrations, and its distance from magnetic disturbances, permits of much work that could not before be performed at any of the Institute buildings.

A discussion followed, and the meeting then adjourned.

BOSTON, April 27, 1899.

The 526th regular meeting of the SOCIETY OF ARTS was held this day in Room 22, Walker Building, Massachusetts Institute of Tech-

[1] *Technology Quarterly*, June, 1899, pp. 135–144.

nology. President Crafts presided. One hundred and fifty persons were present.

The minutes of the last meeting were read and accepted. It was voted, on motion of Professor Charles R. Cross, and seconded by Mr. G. W. Blodgett, that the President appoint a committee to nominate the Executive Committee for the ensuing year.

Mr. T. B. Kinraide, of the Spring Park Laboratory, Jamaica Plain, was then introduced and read a paper on "A New Form of Induction Coil." This unique form of induction coil of great power has been especially applied to the study of discharges by the aid of photographic processes, the plate being balanced on the top of the discharging globe in a dark room, and being developed after exposure to the light of the discharge. This process reveals in a striking manner the marked difference that exists between the positive and negative discharges. The apparatus was exhibited in operation, and photographic plates were shown by the lantern. The figures produced were of extraordinary beauty, and the delicacy of detail was brought out very clearly by the lantern.

A vote of thanks was tendered the lecturer for his very interesting and instructive paper. The meeting then adjourned.

ARTHUR T. HOPKINS, *Secretary.*

BOSTON, May 11, 1899.

The 37th annual meeting, 527th regular meeting, of the SOCIETY OF ARTS was held at the Institute on this day at 8 P. M., with Mr. Blodgett in the chair, and Dr. Bigelow as Secretary *pro tem.* Twenty persons were present.

The record of the previous meeting was read and approved. The Secretary read the Annual Report of the Executive Committee. It was voted that the report be accepted and placed on file.

ANNUAL REPORT OF THE EXECUTIVE COMMITTEE.

The first meeting of the SOCIETY OF ARTS for the present year was held on October 13, 1898. Fourteen meetings have been held, and the following papers have been read:

"Bacteria in Milk; Including their Rôle in Butter and Cheese Making," by Mr. S. C. Keith, Jr.

"Wool, with Practical Features that Enter into the Forming of a Wool Tariff," by Mr. Henry G. Kittredge.

"Metropolitan Water Supply," by Mr. Frederic P. Stearns.

"Geology of the Wachusett Reservoir," by Professor W. O. Crosby.

"Repeated Stresses," by Professor Jerome Sondericker.

"A Description of the Construction and Other Features of the South Terminal Station," by Mr. George B. Francis, and Mr. Henry J. Conant.

"Modern Methods of Steel Forging," by Mr. H. F. Porter.

"The Diesel Motor," by Colonel E. D. Meier.

"The Construction of the University of Virginia, Old and New," by Mr. Theodore H. Skinner.

"An American Railway in Colombia," by Mr. Francis R. Hart.

"The Middlesex Fells Observatory," by Mr. George L. Hosmer.

"A New Form of Induction Coil," by Mr. T. B. Kinraide.

"The Present State of Metallurgy of Lead in the United States," by Professor H. O. Hofman.

The meeting on December 22 was for the purpose of opening the new Pierce Building to the interested public.

A number of new members have been added during the year. At the close of the year 1897–98 the number of Life Members was 53. Five have died this year, leaving the present number 48.

The number of Associate Members a year ago was 323. Of these 1 has died, and 6 have resigned, but 17 have been elected, and the present number is 333. The Life Members who have died during the year are Hon. John Cummings,[1] Waldo O. Ross,[1] Henry Davenport, Hon. F. W. Lincoln, and Colonel Henry Lee. One Associate Member, Captain Alfred E. Hunt, of Pittsburgh, served in the war with Spain, and brought back his regiment without the loss of a man, but has just died from the effects induced by exposure in the trying campaign.

The Board of Publication of last year was reappointed, and the *Technology Quarterly* has been conducted as before, with Dr. Bigelow as responsible editor. During the year twenty articles have been published in the *Quarterly*, besides the Proceedings of the Society of Arts, and Review of American Chemical Research, which have appeared regularly. Of the contributed articles eight are papers that have been read before the Society of Arts, the remaining twelve having been presented by title only. Among the most notable of the latter is an extended paper by Professor S. W. Holman, entitled "On the Telescope-Mirror-Scale Method; Adjustments and Tests."

Respectfully submitted,

(Signed) George W. Blodgett,
Desmond FitzGerald,
Edmund H. Hewins,
Charles T. Main.

There being presented no other reports from committees, nominations for officers for 1899–1900 were next in order.

The Secretary announced that the Executive Committee had voted to nominate Mr. Arthur T. Hopkins to be candidate for the office of Secretary. The report of the Nominating Committee appointed by the President, in obedience to the vote of the Society at the previous meeting, was read. The Committee nominated George W. Blodgett,

[1] See April number of the *Technology Review*.

Desmond FitzGerald, Edmund H. Hewins, Frank W. Hodgdon, and Charles T. Main to be members of the Executive Committee of the Society of Arts for the year 1899–1900.

A ballot having been taken, the Chairman announced that the candidates named above had been duly elected.

The following papers were presented by title:

"On Rapid Methods for the Estimation of the Weight of Suspended Matters in Turbid Waters," by Charles L. Parmelee and Joseph W. Ellms.

"On the Determination of Added Water in Milk," by A. G. Woodman.

"Assaying Telluride Ores for Gold," by Richard W. Lodge.

"Notes on an Unusual Orientation of Phenocysts in a Dyke," by M. L. Fuller.

"On a Method of Measuring the Frequency of Alternating Currents," by Harrison W. Smith.

Professor H. O. Hofman read a paper on "The Present State of Metallurgy of Lead in the United States." Attention was confined to the argentiferous lead ores of the Western States. The subject was treated under three heads: sampling, smelting, and desilverization. Sampling was formerly done entirely by hand, but now it is done largely by machinery.

The first argentiferous ores that were mined were chiefly oxides, and were smelted raw. Most of these ores were exhausted ten years ago. The ores that are being mined at present, as a rule, contain sulphur or arsenic, and must be roasted to drive off these elements before being smelted. Lead ores are roasted in reverberatory furnaces. Formerly the ore was moved by hand, but now this method is largely replaced by the employment of mechanical furnaces.

In smelting it is generally necessary to add a basic flux in order to obtain a good slag. The composition of slags was studied for the first time in 1870, and the greatest contributions to the theory of lead smelting have been made during the last twenty-five years. The products of the blast furnace are base bullion, spiess, matt, slag, and flue dust. The methods employed in the treatment of each of these products were described and the improvements noted.

The desilverization of base bullion is done by cupelling. A great improvement was made by the introduction of the preliminary Parks's method. This consists essentially in adding zinc. It results in the

formation of a silver-zinc-lead alloy which will float upon the lead and is easily removed, while the lead takes up very little of the zinc. The alloy is then cupelled.

A large number of lantern views were exhibited to show the various kinds of apparatus used in the metallurgy of lead, and the improvements that have been made in them.

There being no further business, the Society then adjourned.

R. P. BIGELOW, *Secretary pro tem.*

THE MANUFACTURE AND USE OF BREWING SUGARS IN AMERICA.[1]

By G. W. ROLFE, A. M., and GEORGE DEFREN, S. M.

Before proceeding with this subject it will be necessary to define what is meant by the term "glucose," as there is great variation in the use of this word and consequent confusion in the minds of many. In England and France, apparently, the term is synonymous with dextrose or starch sugar. In America the latter product is invariably called "grape sugar," "glucose" being applied exclusively to the thick, viscid syrup resulting from the partial hydrolysis of starch by acids, a familiar commercial product. In classifications of organic chemistry, the custom seems universal to use the word as a name for a sugar group, although quite recently the word "glycose" is being substituted in the interests of definiteness. In this paper we shall, in referring to the commercial products resulting from the acid "conversion" of starch, speak of solid sugar as "starch," or "grape sugar," confining the term "glucose" to the syrup previously mentioned.

The following outline of the chemistry of the acid conversion, or hydrolysis of starch, will make the details of manufacture more intelligible. When a thin starch paste is heated with a dilute acid, a change takes place much resembling in general appearance that caused by diastase. Investigation shows this difference, — the syrups converted by acid are made up of three components, maltose, dextrose, and dextrin; whereas, in the worts converted by malt (diastase) only two of these are found, maltose and dextrin. (We are speaking of those bodies resulting from the starch alone.) The conditions of formation of these carbohydrates in the two cases are radically different. The conditions of production of maximum maltose in worts, which never exceeds about 80 per cent. of dry substance, are defined by somewhat complicated procedure of heating at varying temperatures, considerable dextrin always remaining unchanged. In acid conversion,

[1] Reprinted from the Journal of the Federated Institutes of Brewing, Vol. V, No. 2, February, 1899. Read before the Society in Manchester, England.

on the contrary, within wide limits at any rate, the composition of the syrups follows fixed laws irrespective of the nature or amount of the hydrolyzing acid or the temperature conditions, these influencing the *rate* of change only. The amount of change at each stage of the conversion is shown by Figure 1, giving the percentage curves of each constituent, the stage of conversion being measured by the change in optical polarization of the syrup. It will be noticed that the original starch paste is pure dextrin, or to be more exact, corresponds in its properties to the primary carbohydrate we call dextrin,

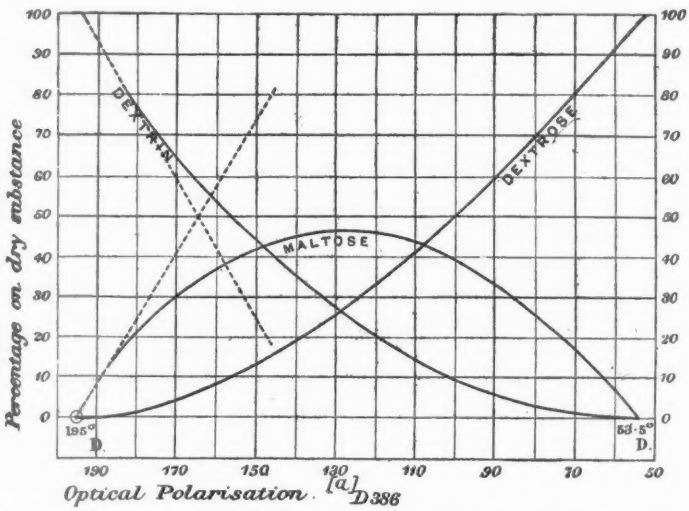


FIG. 1.—RELATIONSHIP OF PERCENTAGES OF PRIMARY CARBOHYDRATES TO OPTICAL POLARIZATION IN HYDROLIZED STARCH PRODUCTS.

(*Products of Diastase Conversion shown by Dotted Lines.*)

which must not be confounded with the commercial products or the alcoholic precipitates so termed, these being in reality complicated combinations. As the hydrolysis proceeds, the dextrin continually diminishes, maltose being rapidly formed, dextrose also appearing almost immediately but increasing at first very gradually.

At what may be considered the middle stage of the hydrolysis, the percentage of maltose reaches a maximum and then begins to disappear like the dextrin, but with more rapidity. Finally, dextrose alone remains in the solution, except some products of decomposition, present in very small amounts, unless the heat is excessive or the acid too

concentrated. The point of conversion for the manufacture of "grape sugar" is then clearly defined by this diagram. In the case of "glucose" two conditions are imperative: (1) The amount of dextrin must be sufficient to prevent the separation of crystallized sugar when the product is concentrated to 45° Bé., or about 84 per cent. (2) Under similar conditions dextrin should not separate out. These conditions limit the conversion stages to those represented by that part of our diagram lying approximately between the polarization figures, 150° and 100°. Commercial glucoses in the market vary in polarization from $[a]_{D\,386} = 145°$ to 120°. As the greatest consumption of glucose is in the manufacture of candies, jellies, and syrups, its composition has been determined by the demands of these trades. The use of glucose in beers, extensive as it is, takes a very small proportion of the total output. On this account there are practically two grades of glucose on the market, leaving out of consideration goods which differ only in concentration: Mixing (syrup) glucose, with a conversion of $[a]_{D\,386} = 120 - 130°$; and confectioners' goods of $[a]_{D\,368} = 130 - 140°$. The best confectioners' goods are commonly about $[a]_{D\,386} = 135°$. There is by no means a rigid standard in the market, however; in fact, many manufacturers grade according to the perfection of refining, the clearer, whiter glucose, independent of its conversion, being specially treated for confectioners' use. Jelly goods differ from mixing glucose merely in concentration, although imperfectly refined candy glucose is often worked up into this grade, as a slight turbidity or tint is of no consequence in jelly manufacture. Mixing glucose is the kind usually bought by the brewer. As we have stated, the composition may vary through wide limits, the proportion of dextrin, for instance, varying in extreme cases about 100 per cent. In short it should be well understood that commercial grading of a glucose is no criterion of the relative proportion of dextrose, maltose, or dextrin, matters of considerable moment to the brewer. The grading of starch sugars being more plainly conformable to the needs of the brewer, their chief consumer, we need not consider them here.

The time at our disposal will permit only the most superficial description of the manufacture of brewing sugars. In general the process consists of three parts: (1) Separation of the starch; (2) conversion; (3) refining. (The diagrammatic scheme (Figure 2) will assist in following this description.) All kinds of what is known as No. 3 or No. 4 corn (maize) are used, the market being the main consideration.

This corn is taken from the cars or the elevator of the works to the steep tubs, which hold 2,000 bushels or more. In steeping, water at 150° F. is used at first, then the steep is allowed to cool till a temperature of about 90° F. is reached. Sulphurous acid is used to prevent putrefaction and assist softening. The steeping lasts from three to five days. The separation of the starch consists of (1) grinding

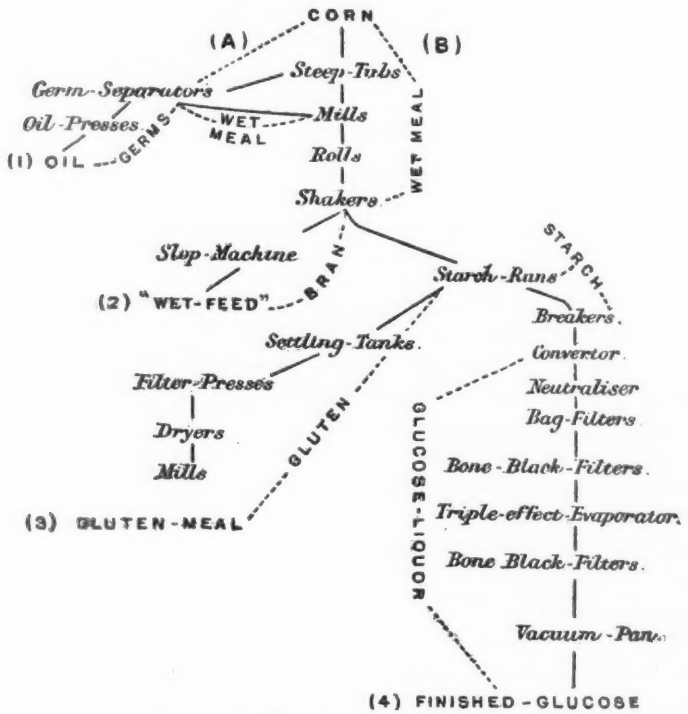


FIG. 2.—SCHEME OF GLUCOSE MANUFACTURE.

the wet grain mixed with water, and softened by steeping; (2) separating the starch grains from the woody fiber and germ by washing through sieves of bolting-cloth, rapidly shaken; (3) settling out the starch from the gluten by subsidence while passing over gently inclined runs ("tables"). The grinding is done so that the starch grains are set free but not ruptured, an important point when yield is considered. The germ is removed separately in many factories, by a patented pro-

cess. This is accomplished by coarse grinding, and running the grain mixed with much water through a long trough, the mass being agitated slowly. The germ which floats is carried off by one channel, the rest of the grain by another. This separation of the germ is an important improvement, since the oil which is contained in it can be readily obtained as a by-product, and the quality of the glucose is much improved by its removal. The grain from the separators is ground and washed on the sieves ("shakers") in the usual manner, and the separated liquor sent over the runs. The thin, highly diluted gluten is allowed to settle, pumped through filter presses, and the dried cake, which contains over 30 per cent. of protein, sold for cattle feed.

The starch collected on the runs, and containing about 50 per cent. of moisture, is now mixed with water to a thick cream of about 20° Bé., preparatory to conversion. Conversion is carried on in large copper boilers at a steam pressure of 30 pounds, hydrochloric acid being the converting agent, the amount used being about 0.0006 of the weight of the starch.

In some factories sulphuric acid is still used as the hydrolyzing acid. In the manufacture of candy goods and certain hard sugars it seems to have some advantages. Oxalic acid has been used for the manufacture of fine candy goods, but the advantages gained are questionable. In the manufacture of grape sugar a much larger proportional amount of acid is used, in some cases up to 1 per cent. or more of the weight of starch. The point of complete conversion is usually controlled by the disappearance of the dextrin precipitate when the liquid is poured into alcohol.

In glucose conversion the acid is mixed with about fifty times its bulk of water, and is run into the converter. Steam is then turned on till a pressure of 30 pounds is obtained. This pressure is maintained while the starch milk is pumped in, which takes about half an hour. Heating is continued after this for 40 minutes or more. "Dirty" starch, containing much gluten, increases the time of conversion 10 minutes or more. The degree of conversion is entirely controlled by iodine tests. By daily practice workmen become quite expert in making these tests, yet from week to week there is apt to be considerable variation in composition when tests are not checked by chemical control, which is rarely the case as far as this point is concerned.

The refining process is in general similar to that of cane sugar.

The analogy is quite close in the case of the solid grape sugars. In the case of glucose, however, there is a radical difference of principle which must not be overlooked. In the refining of glucose the purification must be carried to great lengths, at least as far as color and appearance are concerned. All bodies affecting these characteristics must be absolutely removed from the liquid, or bleached in it, since there is no mother liquor in which they can be deposited, as in the case of a crystalline sugar. On this account the refining of glucose is a much more delicate process than that of sugar.

Neutralization is an important part of the refining, as on the thoroughness with which this is done depends how successfully the albuminoids, calcium and iron salts are removed. As soon as the conversion is completed the liquid is blown out into the "neutralizer," where the alkali, usually sodium carbonate, is added. In many factories it is the practice to cool the liquids considerably before neutralizing, but this seems unnecessary when the alkali is added properly. The liquid when neutralized should show only the acidity caused by carbon dioxide or the weakest vegetable acids. The properly neutralized liquid is clear and of a bright amber color, but contains large flocculent masses of coagulated gluten, which, in a test tube of ordinary size, form a layer about half an inch thick. When the proper point of neutralization is attained, this layer is greenish-drab, owing to the precipitated iron.

As in sugar refining, the precipitated matter is removed by bag filters, this often being supplemented by a press filtering. In the case of highly refined glucoses, precipitants are sometimes used, such as alum. The tendency seems to be for manufacturers not to push this part of the refining to greatest advantage, but rather to depend on a liberal use of bone-black to do much of what it would seem could be accomplished by less expensive means in preliminary clarification. The bone-black treatment is quite complicated, not only in the details of filtering but in the preparation of the black. Since the slightest trace of alkali in contact with the hot liquor will produce a brown stain of caramel, removable only to a limited extent by bone-black, the black itself must be freed from all traces of ammonia or caustic lime by a careful "tempering" with hydrochloric acid or some similar treatment, and subjected to a careful washing to remove soluble salts of iron and calcium. The glucose liquors are, as a rule, put over the bone-black twice; first at their original concentration, about 18°

Bé., and again after concentration, to 28 — 30° Bé., the denser syrup going over the freshly tempered black. The revivifying of the black is carried out on lines similar to those of cane sugar refining.

The "heavy liquor" goes directly from the filters to the vacuum pan in most modern factories. Formerly a preliminary filtration was necessary to remove the calcium sulphate which separated out, but with the use of hydrochloric acid conversions and neutralization with soda, this is avoided. In the final concentration sulphites are added in amounts varying from 0.008 to 0.050 per cent. SO_2.

The function of these sulphites is as follows: (1) To prevent oxidation and consequent coloration in the final concentration due to formation of caramel-like bodies, and sometimes ferric salts; (2) to bleach; (3) to prevent fermentation of the lesser concentrated finished products, as the thinner mixing syrups; (4) in candy goods, as a preventative of oxidation in the candy kettle. Confectioners' goods are much more heavily "doped" than others. There is a tendency among manufacturers to excessive use of sulphites in all classes of goods, a matter of some interest to the brewer.

The refining of grape-sugar liquors is practically identical with that of glucose. The concentrated syrups are drawn off into pans or barrels and allowed to solidify, a "seed" of crystallized sugar often being added to facilitate crystallization. Anhydrous grape sugar is made in a similar way from a syrup which is refined at lower concentrations throughout the process in order to obtain a purer product. In this case the "seed" is selected with the greatest care from absolutely pure anhydride, all hydrated crystals being scrupulously excluded. The crystallization is complete in about three days, when the sugar is purged in centrifugals. The purged liquors are often worked up into the "climax" sugars, a dark product familiar to most brewers. Of late years these sugars have been further refined as a white product, and even made directly by merely solidifying the anhydrous sugars as a concrete without purging. As is well known, these sugars also are often put on the market as "chips." Glucose syrups are usually made at six concentrations: 39°, 41°, 42°, 43°, 44°, 45° Bé. Mixing goods are usually finished up at 39° or 41° Bé.; 41° mixing glucose is the grade usually sold to brewers. The higher concentrated products are confectioners' or jelly goods, the former being characterized by greater perfection of refining and a large amount of sulphites. These are often whitened with methyl-violet.

A few words as to the manner of taking concentration determinations may not be amiss here, as there seems to be considerable confusion of ideas on this point. This is not surprising when we remember that there are over thirty different Beaumé scales in existence. The glucose manufacturers do not use the same scale as the sugar refiners, who employ Gerlach's modification. The glucose scale is practically identical with that used by the alkali manufacturers, and has the following conversion formula for the density: $d = \frac{144}{144 - Bé.}$ Owing to the great viscosity of glucose, the readings are taken not at the standard temperature of the instrument (60° F.), but at 100°. The determination is somewhat difficult and tedious. The slightly warmed glucose is poured into a cylinder, preferably of glass, which is placed in a water bath at 100° F. At the end of half an hour or so, the glucose will have reached the temperature of the bath, and the air bubbles will have escaped. A Beaumé spindle, reading to fifths, is then cautiously lowered into the glucose and allowed to come to equilibrium, which in the more viscous samples takes some minutes. With care the determination can be made on a Westphal balance. All samples of glucose should be tested for density, as the viscosity in goods of different conversions varies to a marked degree. A low converted sample of moderate density will apparently have much more "body" than a high converted glucose much more concentrated.

As, apart from concentration, the quality of commercial glucose is largely judged by its appearance, it will be interesting, possibly, to consider briefly some of the turbidities and colorations of the commercial products, their causes, and actual influence on the quality of the glucose. A well refined glucose is practically colorless and clear. If a white glass cylinder is filled with glucose, the color of the sample can be seen as well as any turbidity. If the color is a pure white, the sample is dyed, as can be proved by exposing it to the light for a few days, although this coloring is rarely done so well that a close inspection will not reveal the violet tint. As all glucoses darken slightly on exposure to the light, the color balance soon becomes disturbed, and the presence of the dye is made more evident. If no dye is present, the glucose, unless quite turbid, will show some color, usually green or yellow. These tints are almost invariably present, and seem to be caused by traces of iron salts and vegetable coloring matters. They are of little consequence, except as indicators of the thor-

oughness of the refining, and hence the removal of albuminoids and oil. These impurities affect the flavor of the product. Dyeing, therefore, likewise only concerns the brewer so far as it may be the means of compelling him to pay a high price for low-priced goods. A reddish-brown discoloration is the result of excess of alkali, as a rule either through imperfect neutralization or defective treatment of bone-black.

As to turbidity, cloudiness caused by faulty conversion, separation of dextrins in one case or sugar in the other, is in these days of rare occurrence. A smoky appearance is often caused by bone-black dust, or in some cases from iron sulphide, when a large quantity of new black is used in refining; these, of course, are the results of improper preparation of the black. White cloudiness is caused either by calcium salts or by organic growth due to fermentation. The former may be sulphate or phosphate. Sulphates in goods converted by hydrochloric acid are in the main introduced through use of impure acid, or in sulphite liquors; phosphates, from excess of "tempering acid," or incomplete washing of the black. The clouds due to fermentation, which naturally are more common in goods made in hot weather, are usually the result of storing thin liquor (in process) at too low a temperature. Of course the fermentation organisms can easily be identified by the microscope. A quick way of identification is to acidulate the sample with hydrochloric acid, when the ferment cloud remains undissolved. It is evident that the presence of foreign ferments possibly, even probably, in a state of activity, is a matter of no little concern to the brewer. Already attention has been called to this by Dr. Krieger, in an article in the *American Brewer* of September, 1896, on "The Use of Turbid Glucose in the Brewery." The author very properly advises a thorough boiling of such glucose in the wort. He, however, confines himself to finished goods which have fermented, presumably after they have left the factory, but often glucose to all appearances free from ferment will show presence of organisms as described. It would seem decidedly doubtful whether these organisms are entirely killed by the moderate temperature of the vacuum pan and the light treatment with sulphite which such goods often get.

While referring to this article of Dr. Krieger's, we may also call attention to an important paper by the same author, on "The Manufacture of Starch Products," in the *Zeitschrift für Spiritus-Industrie*, 1894.

It is evident that the calcium salts have no influence on brewing in the quantities present in glucose.

The valuation of the solid starch sugars is practically based on their dextrose content. Whiteness of late years seems to be more of a desideratum than formerly; hence the practice of dyeing is becoming common. The principal mineral impurity objected to is iron. This is rarely present in more than traces. A delicate test for iron in sugars or glucoses is made with cochineal. Sulphites must be first removed, and the solution made neutral or faintly alkaline. If iron be present, the pure crimson of the cochineal gradually passes into violet. We think in the past brewers have been more alarmed than injured by the iron in glucose. In the first place iron is only present in glucose in traces, never enough to cause damage in brewing; and secondly, if by any chance iron be present, probably it is precipitated in the form of tannate, which is removed in the "hop back," or through settling in the settling tuns. Moreover, most brewers will find that their brewing waters generally contain more iron salts than does any glucose, and also if they use iron mash tuns, or iron rakes in these tuns, some iron will always pass into solution by the action of the small amount of lactic acid in the malt, which would also be considerably more than that which occurs in glucose.

Our attention has been called to an iridescence on the surface of wort in the copper, containing much glucose. This was undoubtedly due to traces of corn-oil, which occasionally is present in finished goods.

We have omitted mention of any method of determining degree of conversion of glucoses, as we have already published this in detail (*J. Amer. Chem. Soc.*, October, 1896).

Solutions of grape sugar show the same characteristic colorations and turbidities, in a greater or less degree. Usually they show caramel tints, owing to the decomposition products, especially in inferior goods.

No exact statistics are at hand by which we can state with positiveness just what is the amount of brewing sugars made and consumed in the United States. The glucose industry uses about 35,000,000 bushels of corn (maize) annually in making about 1,000,000,000 pounds of glucose. As far as we can estimate, from 15 to 20 per cent. of this is consumed in brewing in the United States; about 160,000,000 pounds goes to England, a considerable portion of which, we understand, is used in candy making.

Apart from the foregoing brief account of the manufacture of commercial glucose and grape sugar, it is the object of the present article to show how these products can be, and in many cases are, used by lager and ale brewers.

There is a marked prejudice among brewers against the use of glucose as a substitute, yet these same brewers use large quantities of corn grits and corn flakes, forgetting for the moment that commercial glucose is really nothing more than common corn starch hydrolyzed by acids under steam pressure. This has been already explained in the first part of this paper, and shows that dextrose, in addition to dextrin and maltose, occurs in glucose, whereas diastase forms only these two latter from starch, the hydrolysis ending before the maltose is decomposed into dextrose.

Malt substitutes may be divided into two classes: those in which the extract is obtained by a mashing process with malt, and those in which the extract is already formed. The first comprises maize, rice, wheat, prepared corn, and corn flakes, etc. When using any of these substances for brewing purposes, certain proportions of them are either added directly to the malt in the mash-tun, or else the starch in these substitutes is first gelatinized in a separate vessel and rendered soluble by a little ground malt, and afterwards added to or sparged over the goods in the mash-tun. To the second class belong refined cane sugar, invert sugar, glucose and grape sugar, and refinery syrups.

These substitutes are used for some one or more of the following reasons:

1. Ease of manipulation.
2. Economy.
3. An improvement in, or changing the character of the finished beer.
4. Quick clarification.
5. Flavor.
6. Priming.
7. Pale beers.

1. When an ordinary pure malt wort has been prepared according to the established rules, it is simplicity itself to add glucose to this, either in the underback, copper, or hop back. The whole is mixed by boiling or stirring, and then fermented as usual. The amount of glucose or grape sugar to be added to the malt wort should be based upon

the same considerations as when using corn grits, corn flakes, and other similar substitutes. Glucose comes in barrels highly concentrated, and at once gives a maximum return for material used. No extract is lost through non-saccharification of any starch, as is the case with corn grits, etc. The only care to be exercised is that the barrel be steamed out, thus insuring complete removal of all glucose which might be attached to the staves. This is very much simpler than making a corn mash. It takes but a few minutes, requires no careful manipulation or expensive apparatus, and consumes but little steam. Another great advantage of glucose substitution is that the gravity of the wort may easily and quickly be brought to any desired stage — an advantage the brewer keenly appreciates, when through some mishap or change of malt he finds his wort several tenths of a per cent. below the accustomed gravity.

2. From an economical standpoint glucose and grape sugar are sometimes used, although at times the prices of these substitutes have been higher than malt or prepared grain, which would contain equivalent amounts of extract. A little more than a year ago American glucose was selling pound for pound of extract at less than half the price of malt. To-day the market conditions have placed the prices of glucose and malt on a more uniform basis, although it is still a decided economy for the brewer to use glucose at present quotations in combination with malt.

If brewers made a few calculations upon the price of the extract in glucose in competition with raw corn grits, prepared corn flakes, etc., they would easily save money at various times. There is no economy in purchasing 43° glucose at $1.60 (6*s*. 6*d*.) when corn grits sell at $0.96 (4*s*.) per 100 pounds; and yet we have brewers here who tell us they use glucose because it is the cheapest malt substitute obtainable, where if a little calculation were made, surprising results would appear.

3. There are many brewers who do not use glucose solely for reasons of economy. Glucose and grape sugar are used very extensively in America for the purpose of improving the finished beer. If used judiciously, there is no question that these substitutes improve this article. Glucose contains only a very small percentage of nitrogenous matter, and it has always been believed that the smaller the percentage of nitrogen in the wort the sounder it would be. This is a delightfully easy explanation, and we regret to say we do not believe

the statement entirely. Although this may apply when small amounts of sugars are used, and may have an important bearing on the subject, the amount of nitrogenous matter may be reduced to such small proportions that the beers are really thin in taste, and are derisively styled "corn beer," "glucose beer," etc., with considerable justice. Some nitrogenous (proteid) compounds in beer precipitate after standing or when cooled. In itself this may do no harm in affecting the taste, yet very few to-day wish beer so clouded with albuminoid turbidity that it is almost impossible to look through it.

It is here, then, that the addition of glucose is an advantage. A well refined glucose contains almost no nitrogenous matter, and when added judiciously, commensurate with the quality of malt used and the kind of beer desired, the results obtained well warrant the employment of this substitute. The wort obtained from poorly manufactured malt will not permit the use of much substitute, whereas a fine malt wort may have as high as 30 to 40 per cent., or even more, glucose added to it without endangering the quality of the beer. Many lager beer brewers use as much substitute as this in their wort and derive good results. On the other hand, the beer must have a certain "full-bodied" taste and retain its foam-keeping qualities, and one of the easiest ways of failing in these requirements is to add too much grape sugar or glucose. We know of one case where the amount of glucose was 65 per cent. of the entire raw material used, and although what was called "beer" resulted, people are usually fastidious enough not to desire any more of it. Beer is not simply a fermented glucose solution.

Many brewers say they wish their wort brewed at 12, 13, or 14 per cent. Balling. If it possess this percentage of extract their wishes are satisfied. The composition of the wort and the dependent degree of attenuation of fermentation troubles them but slightly. Yet beer may have a large percentage of extract, and still be thin in taste; while there are beers with 1 or 2 per cent. less extract, which possess a better head of foam, are more full-bodied than heavier articles, and are considered better in quality in every respect. Each brewer must use such amounts of glucose or grape sugar as he finds his trade will warrant.

There is another matter which should be touched on here, and that is, the choice of kind of glucose, as the following examples will indicate. A malt wort mashed at a low initial heat and brought up slowly

to a tap heat of 163° F., with a gravity of 10 per cent. Balling, if mixed with a glucose of a specific rotatory power of $[a]_{D\,386} = 145°$ until the gravity were 14 per cent. Balling, and then fermented, it would have about $1\frac{1}{2}$ per cent. more extract in the finished beer, and conversely less alcohol, than if the malt wort were mixed with glucose of $[a]_{D\,386} = 120°$ specific rotation, and brought to the same gravity. The difference would be even more marked if the finished wort were made up of 4 per cent. grape sugar of a rotation of 70°, in which case the amount of extract in the finished beer would be small, and the percentage of alcohol correspondingly high.

This is accounted for as follows: A normally converted glucose of a rotation of $[a]_{D\,386} = 145°$ contains, in dry substance, about 40 per cent. dextrin, 17 per cent. dextrose, and 43 per cent. of maltose. The dextrose ferments quickly, while only a part of the malto-dextrins is decomposed, these complex dextrins not fermenting until broken down by the action of the invertase of the yeast. A glucose of 120° specific rotation would, on the contrary, contain only 21 per cent. of dextrin, 34 per cent. of dextrose, and 45 per cent. of maltose in the dry substance; while a highly converted glucose — in other words, commercial grape sugar — of 70° specific rotation would have its dextrin reduced to about 2 per cent., while the amount of maltose, dextrose, and decomposition bodies, gallisin, etc., would constitute the remaining 98 per cent. The importance of an intelligent examination of the glucose is evident, for on this selection the composition of the finished beer will largely depend, especially when the amount of substitute is added with a liberal hand. Therefore a glucose should be selected and its delivery insisted upon, which will give a definite result. We are optimistic enough to believe that the day is coming when the brewer will state whether he wishes the glucose of a specific rotation of 145° or of 120°. One could be made about as easily as the other, and though they may look alike, still the results obtained by using them side by side would be decidedly astonishing in the finished product. The mixing and confectioners' trades have been the means of placing the glucose of to-day on the market, and the brewers simply take what is set before them.

By employing higher mashing heats, and adding a higher converted product, *i. e.*, grape sugar, we obtain a finished beer which possesses nearly the same percentage of alcohol and extract as a beer made by low mashing heats, to which low converted glucose of 130–135° spe-

cific rotation has been added. This is explained by the fact that high mashing heats cause the diastase of malt to act on starch in such a way that the amounts of maltose formed are small in comparison with dextrin, as has been so clearly demonstrated through the brilliant researches of Messrs. Brown, Morris, Heron, and O'Sullivan. If grape sugar be added to this, the amount of fermentable material necessarily increases, the percentage of alcohol also increases, while the extract diminishes. An analogous explanation would apply to the use of low mashing heats and low converted glucose of, say, 130° rotation.

To use sugars without reducing the stability of the wort, they should possess nearly the same compositions in malto-dextrin and fermentable sugars as the original wort made entirely from malt. There is no question that grape sugar, 70° rotation, is most advantageously employed in the manufacture of stock ales, as the percentage of dextrose in this substitute is very high and it is easily fermentable. Stock ale, to keep well, should be highly attenuated, *i. e.*, the beer should contain a large percentage of alcohol and a small percentage of extract, and that of a composition not easily broken down by the ordinary brewers' yeast. There are brewers here who, in using a low initial mashing heat, employ a small amount of glucose of 130° rotation, and report no harmful effects; but the majority of ale brewers prefer to use a higher mashing temperature and add more grape sugar instead, a process which gives very satisfactory results.

The ale and lager beer brewing industries have been aided within the past few years by the use of so-called "carbonators." These artificially charge the "still" ale or beer with carbonic acid gas, which gives it "life." Beer that has been thoroughly fermented, cooled, filtered, carbonated, and then bottled, though a comparatively rare article to-day, will surely become common before many years go by. A carbonated stock ale made by ordinary methods, and with the addition of grape sugar or high converted glucose, should make a very palatable article.

4. What has been said in the preceding paragraphs has a bearing on the fourth condition, that of clarification. Clarification in sugar-brewed beers, *i. e.*, beers in which high converted grape sugar is added, is quicker than in all malt beers. This is probably on account of the reduction of the viscosity of the wort, owing to the substitution of the dextrin and malto-dextrins, by fermenting the sugars, which causes

a more ready elimination of the yeast, as well as a more advantageous action of artificial finings when used in the "chip" casks in lager beer manufacture, and even in ales which are to-day treated after the main fermentation, very much as ordinary lager beer.

Bright, sparkling, draft ale is very much desired at the present day, and it is essential to have the fermenting wort clarify quickly. This is easily accomplished by simply employing grape sugar or high converted glucose of 100–110° rotation. The dextrose ferments rapidly, the solution becomes less viscid, the yeast is eliminated more easily, and filtration becomes simpler. This is very advantageous in bottling beers, which should be free from turbidity, in that the addition of glucose or grape sugar has reduced the amount of nitrogenous matter to a minimum, thus requiring less to be removed by cooling.

It was formerly claimed that the yeast would degenerate if glucose were put into malt wort on account of diminishing the nitrogenous matter. This has been proved entirely fallacious by practical experience. It has been shown that yeast can ferment considerably more sugar in wort than it is called upon to do on the average, although a limit must eventually be reached beyond which the yeast will not act. Yeast does not decompose sugar into alcohol and carbonic acid gas indefinitely without some additional nourishment, and this necessarily implies a certain quantity of nitrogenous matter in the fermenting wort. Quick clarification by the addition of grape sugar should not be too diligently sought, to the detriment of the life of the yeast.

5. A pure malt beer is prized by many. It generally possesses a good head of foam, is full-bodied, and is characterized by a distinctive flavor. It was at one time believed that foam-holding capacity and full-bodiness were due to dextrinous compounds, but this idea has died out. It is to-day considered that peptones and albumoses are the real causes of foam-keeping and full-bodied taste, and if mashing be carried out so that peptones are formed in maximum quantity, the amount of sugar substitute can be considerably increased without hurting the beer. The distinctive character of stock ale is obtained by fermenting wort to a low gravity, thus increasing the amount of alcohol to a maximum, and reducing the extract. The percentage of alcohol in beer depends on the amount of fermentable sugars present. If this be high, the alcohol percentage is high, and *vice versa.* Grape sugar consists almost wholly of dextrose, which is entirely fermentable, and when this is added to malt wort and fermented, the

percentage of alcohol rises, and gives to the stock ale its peculiar tart flavor. This is the real reason for its employment in stock ale. Mild running ales, pale ales, and pale lager beers, on the contrary, have generally a lower percentage of alcohol, and it is in their preparation that glucose syrup is added as a substitute.

6. The subject of "priming" is pretty well known to the average brewer. So-called "kräusening" in lager beer consists in injecting about 10 per cent. of a vigorously fermenting wort into the storage lager beer in the chip cask; whereas "priming" is simply an addition of a grape sugar solution to the storage ale which is then bunged down. The sugar present ferments, thus forming alcohol and carbonic acid gas; the latter impregnating the ale, gives it the requisite "life." Grape sugar is preferable to glucose syrup in priming, on account of the quick fermentation without prolonged decomposition, as is the case with glucose.

7. Glucose and grape sugar are very extensively used in the United States for pale beers. The American people have become so accustomed to drinking light beers, that a very great demand has been created for them. Dark beers are not much desired. In manufacturing pale beers the brewer demands malt kilned at a low temperature, and adds to this a considerable quantity of substitute, be it corn grits, corn flakes, or other corn product, rice, etc. Glucose is added directly to the wort in the copper, and then fermented as usual. The ordinary malt wort possesses a very considerable amount of color, even if the malt employed has been dried at a very low temperature. A glucose or refined grape sugar solution, on the other hand, is practically colorless, and when added to the malt wort necessarily gives the article a much lighter appearance. An attractive beer is as essential as a palatable one, and where a good appearance and a fine flavor are combined, the brewer's labors are accomplished.

In conclusion, we would say that we hope these somewhat fragmentary notes on the manufacture of glucose and grape sugar, and their application to brewing purposes, will accomplish their sole object; that is, a more extended discussion and study of these useful materials, carried on with the conscientiousness and thoroughness which their importance deserves.

APPARATUS FOR TESTING INJECTORS.

By CHARLES FRANCIS PARK, S. B.

Received August 4, 1899.

The difficulties in obtaining correct injector tests are realized by all who are familiar with these instruments. Several methods of testing are in use, but all have properties that are apt to lead to unsatisfactory results. So, in whatever method we may adopt, there will be present some objectional feature; and in the design of the apparatus described in this paper, the method of testing which was selected was the one whose difficulties could be overcome with the maximum accuracy.

As this paper will be of interest to those only who are somewhat familiar with the testing of jet apparatus, or the like, no discussion of the action of the injector nor of the several methods of testing that are in use will be given; and I will proceed at once to describe the apparatus that has been designed and placed in the Engineering Laboratories of the Massachusetts Institute of Technology.

The problem before us is to obtain the amount of water pumped, the steam used, the time occupied, and the conditions under which the injector has done this work, namely: the pressure of the steam used, the quality of this steam, the pressure under which the water was delivered, the height through which the water was lifted, or the suction, and the temperature of both the suction and the delivered water.

The quantity of water pumped is found by measuring both the suction and the delivered water by direct weight. The amount of steam used for the given time is the difference in weight between the delivered and the suction water for the same time, as the delivered water contains the steam used, condensed. The conditions of working, under which these quantities have been determined, are obtained in a manner clearly shown by the description of the apparatus.

The injectors have been mounted and piped in such a way that a test can be run on either one without any change of the connections other than the manipulation of two valves. Steam is supplied to the

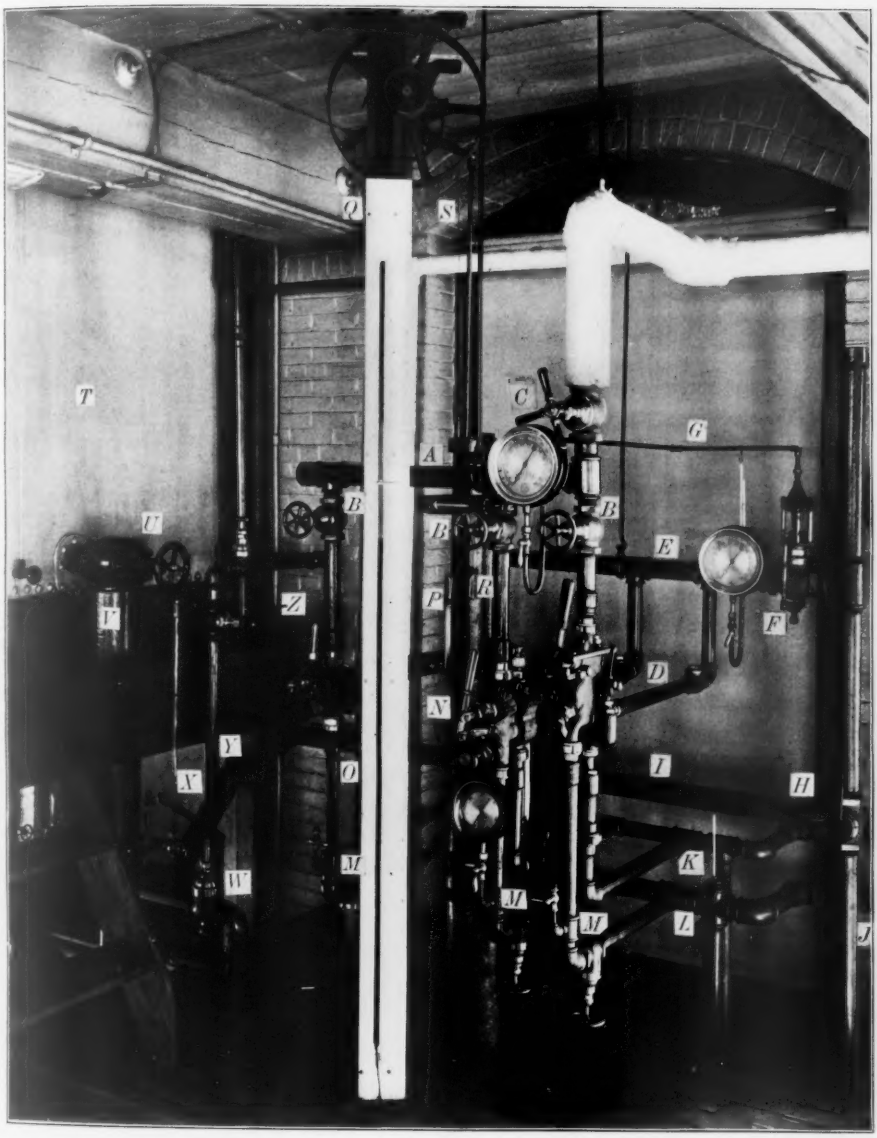


FIG. 1. — APPARATUS FOR TESTING INJECTORS.

injectors (Figure 1) from the pipe *A*, through the branch pipes and valves *B*, one of the latter being opened for the injector to be tested. A gauge connecting with the pipe *A* gives the pressure of the steam, which pressure is regulated by the throttling valve *C*. A throttling calorimeter (not shown in the figure) can be connected with the steam pipe *A*, and the quality or priming of the steam thus ascertained.

The delivered water passes through the branch pipes and check valves *D*, into the delivery pipe *E*, the pressure of the delivery being maintained in this pipe by the back-pressure valve *F*. The pressure of the delivered water is taken by a gauge connected with the pipe *E*, and a thermometer inserted in this pipe gives its temperature. A second thermometer is usually hung near the first in order to apply a correction for stem exposure.

The back-pressure valve *F* has been designed to automatically hold the delivery pressure equal to the steam pressure, or a little in excess of it for whatever variation there may be in the latter. The construction of this valve is shown by Figure 2. It will be noticed that the valve stem has been extended, and that it carries at its upper end a piston which presses against the under side of a rubber diaphragm. Above this diaphragm is a small chamber which is filled with water and connected with the steam pipe *A* (Figure 1) by a small pipe *G*. There always exists, then, in the chamber a pressure equal to that in the steam pipe, and this pressure, acting through the diaphragm on the piston, places a load on the valve stem that holds the valve disc to its seat. Now, if the area of the piston is equal to the area of the valve opening, a pressure will have to be created in the delivery pipe equal to that in the steam pipe before the valve can be opened. Thus, this valve will hold the delivery pressure equal to the steam pressure, as any variation in the latter will result in a corresponding change in the load on the valve disc. As the size of the valve is large in comparison with the size of the injectors, and as it throttles to a high pressure, the valve movement is very small and hardly perceptible.

In reality an injector when feeding a boiler is required to work against a delivery pressure a little in excess of the steam pressure on account of friction, resistance of valves, etc., so we have made the piston of the back-pressure valve a little larger than the valve opening to meet this condition.

If it is desired to run a test with the delivery pressure considerably in excess of the steam pressure, an additional load can be placed

on the valve disc by the use of dead weights, which can be hung on a yoke that is attached to the valve stem clearly shown in the figure. The ultimate pressure of delivery, or the pressure against which the

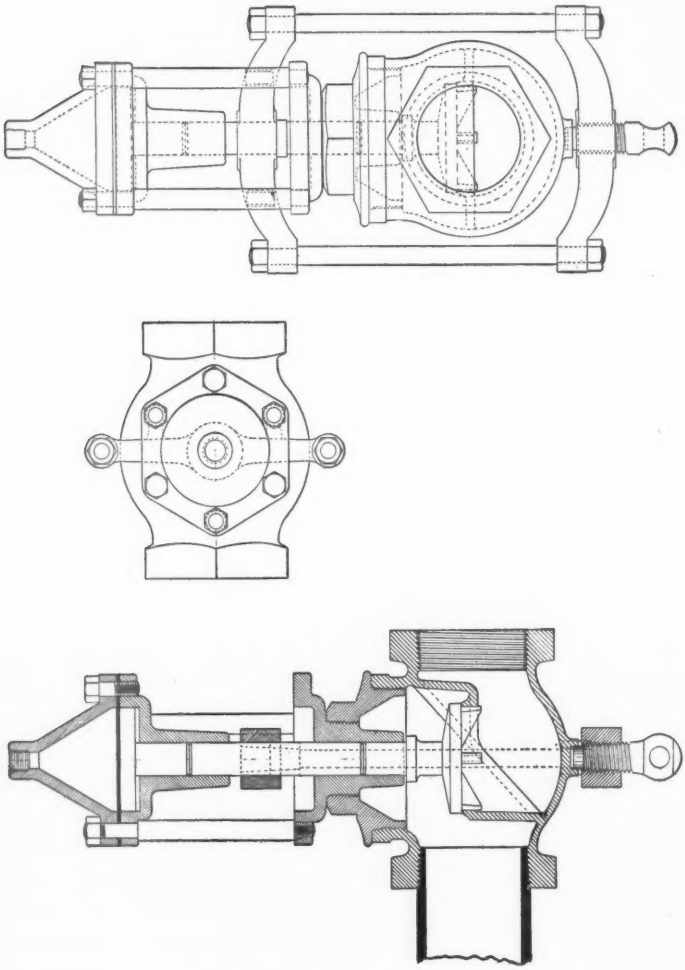


FIG. 2. — 2½" BACK-PRESSURE VALVE.

injector fails to work, can be found by setting up a screw at the bottom of the valve yoke, which will draw the valve disc to its seat and increase the pressure until failure.

The delivered water after leaving the back-pressure valve passes through a three-way cock *H* (Figure 1). This three-way cock causes the water to flow either through the pipe *I*, which is a waste pipe, or through the vertical pipe *J*, which empties into weighing tanks on the floor below. To prevent a loss in weight of the delivered water by evaporation, a cooler has been placed on the delivery pipe *J*, and the weighing tanks are kept covered.

The overflows of the injectors are connected by branch pipes to one main overflow pipe *K*, which leads to a separate weighing tank. The waste through the overflow during a test is collected in this overflow tank and weighed.

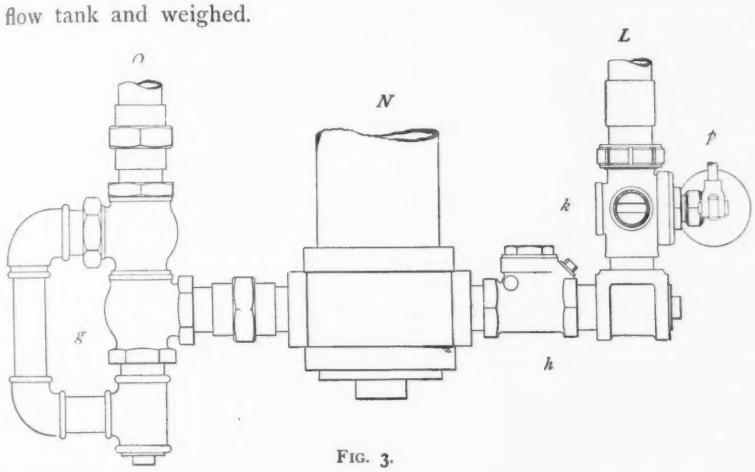


FIG. 3.

The suction pipe *L* is connected to the injectors through the branch pipes and gate valves *M*, one of which must be opened for the injector to be tested. The suction water is drawn from a 6-inch standpipe *N*, the connection being made at its lower end. This connection is shown in Figure 3.

The feed water is supplied to the standpipe *N* by the supply pipe *O*, the supply being controlled by a balanced valve *g*, the action of which will be considered later. This feed water passes from the standpipe to the suction pipe *L* through a check valve *h*, and a three-way cock *k*. This three-way cock *k* is of a special design, and is inserted here to furnish means of emptying the standpipe and adjusting the lift. The construction of this cock is shown by Figure 4. It will be noticed that it gives a full opening to the suction pipe in one position

(the position when running the test), and that when thrown in its other position it connects both the standpipe and the suction pipe with a

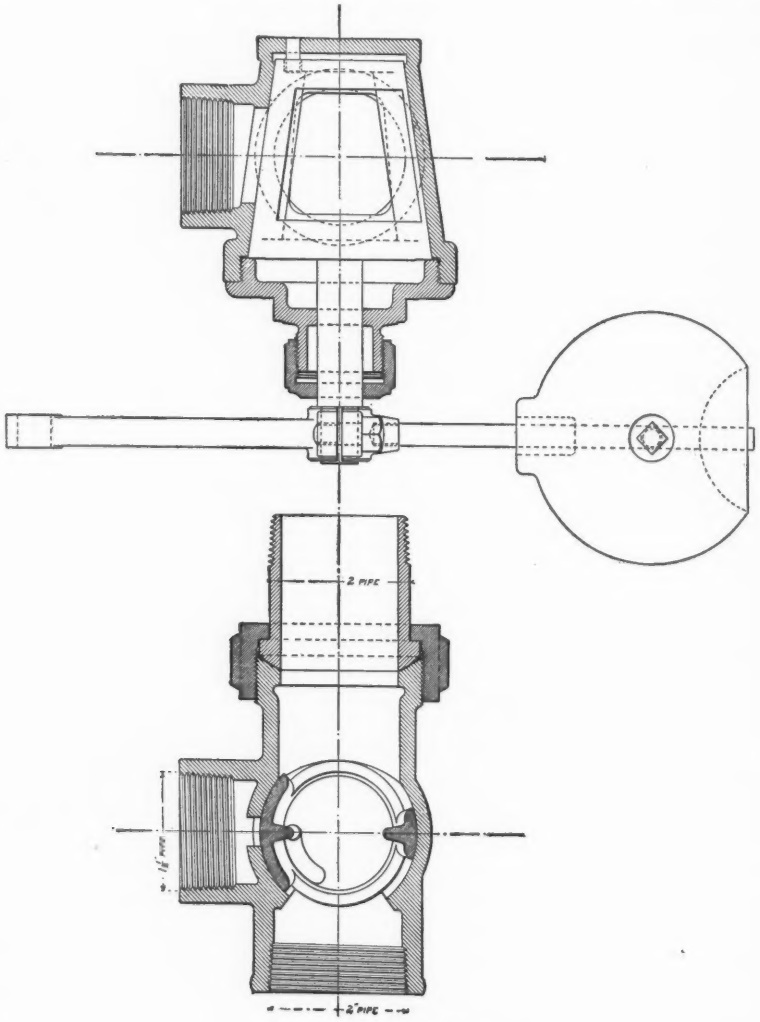


FIG. 4. — THREE-WAY COCK.

third pipe, which is a waste pipe. It is operated through a rod p, and a system of levers by the handle P (Figure 1).

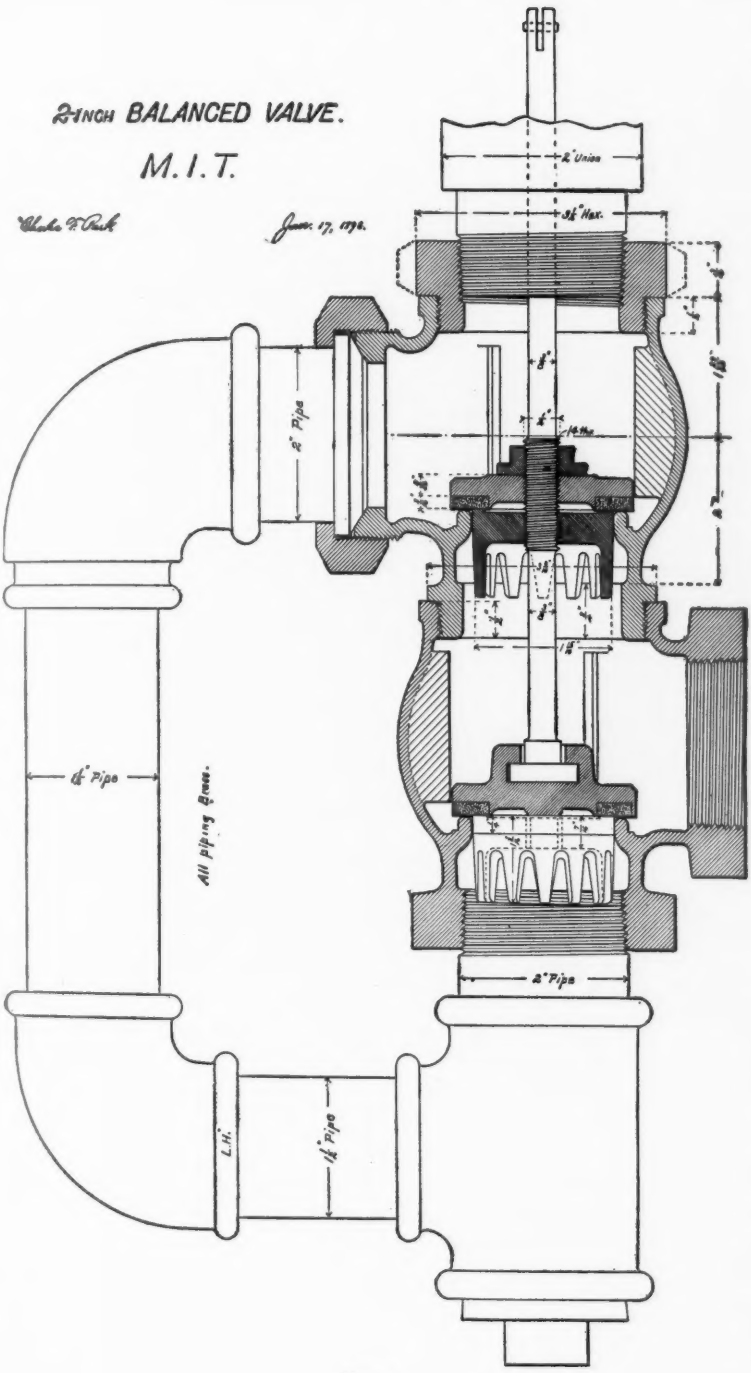

2-INCH BALANCED VALVE.
M. I. T.
Charles T. Main
June 17, 1890.
2" Union
3½" Hex.
2" Pipe
1½" Pipe
All piping 2 ins.
L.H.
1½" Pipe
2" Pipe

FIG. 5.

It is obvious that a three-way cock of such construction is necessary, as an ordinary one would cut down the suction opening on the run, and would connect only the standpipe with the waste. Both the suction and the standpipe must be emptied together. Otherwise a starting test for lift cannot be made.

The balanced valve *g* (Figure 3) is shown by Figure 5. Its construction is somewhat peculiar, in that it was made from two globe valves, thus avoiding the making of new patterns. The valve discs are provided with leather seats, and both are attached to one stem. To the upper end of the stem is connected a chain which operates the valve. The only feature that may not be clearly seen from the figure is the serrated disc that is placed under each valve disc proper. These discs are made to nearly fill the valve opening, and are tapered off and serrated to within about one-half an inch of the valve seats. Without these discs it is clearly seen that the valve when running a minimum supply would be open only a very small amount, and would in consequence chatter or pound and give trouble. By the use of these serrated discs, the valve must be raised a considerable amount from its seat before an appreciable flow can be maintained.

The level of the water in the standpipe is controlled automatically by a float which acts on the balanced valve through the regulating device shown in Figure 6, and also in Figure 1.

This device is hung from the ceiling, and consists of a shaft that carries two pulleys and a gear, each fixed to it, and two loose levers. The pulleys serve as drums. The larger one holds a flexible brass wire cord that connects with the float in the standpipe. The smaller one holds a fine steel wire, to which is hung an iron weight that moves up and down in the weight box *Q* (Figure 1). This weight acts as a counterweight to the float. The float is made of sheet copper, and is cylindrical in shape, about 5 inches in diameter and 12 inches long. It has four vertical fins on its outside to prevent it from becoming lodged in the standpipe, and it is loaded with shot to the proper buoyancy.

The float cord leaves the larger pulley from the right-hand side, and the counterweight is hung from the left-hand side of the smaller pulley. The counterweight with its small leverage is not sufficiently heavy to balance the weight of the float with its larger leverage. So, if the float were free to fall it would turn the shaft to the right and raise the weight. If the float were raised, the weight would keep the

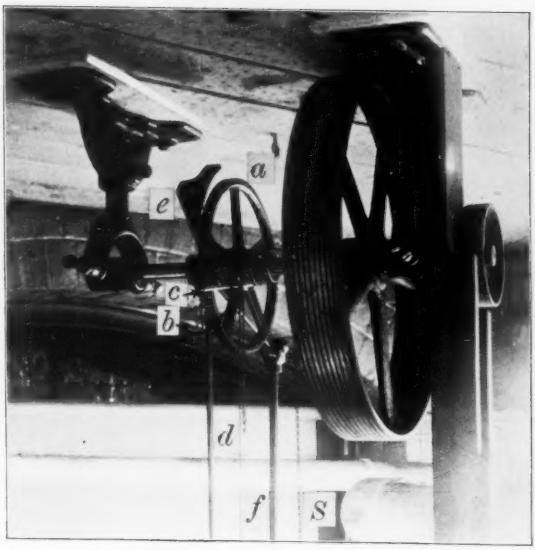


FIG. 6. — AUTOMATIC REGULATOR.

float cord taut and turn the shaft to the left. Now as the float moves with the water level in the standpipe, any change in this level will cause the shaft to turn in either the one or the other direction. The counterweight, then, will move with any such change, and can be made to serve a double purpose; so an index has been fixed to it which will register on the graduated scale of the weight box the water level in the standpipe or the lift. The water level can also be ascertained by gauge glasses that are connected with the standpipe at fixed intervals. These gauge glasses furnish means of graduating the scale on the weight box, and also serve as a check on this scale. An adjustment can be made at any time by a turn-buckle that is attached to the weight for such a purpose. A helical groove (or a coarse square thread) has been cut on the face of both pulleys for the cords to run in, so they will not be wound on themselves, and thus prevents any change in the effective diameter of the drums.

The gear *a* (Figure 6) acts as a ratchet wheel, and works the lever arm *b*, through a pall *c*, carried by the arm. To this arm is fixed a brass chain *d*, that is attached to the stem of the balanced valve. Now to hold a constant water level in the standpipe, water must be admitted as fast as it is withdrawn. This is accomplished automatically as follows: Suppose the water level falls, then more water must be admitted; but when the water level falls the float moves with it and turns the shaft to the right. The gear, then, turning to the right with the shaft, will move the arm by means of the pall, in the same direction, and cause the chain to raise the valve and admit more water. If the water level rises, then the float rises and the counterweight will turn the shaft to the left. This movement of the shaft and gear to the left will allow the arm to fall and the valve closes by its own weight.

The closeness with which this device will regulate depends upon the resistance of the mechanism to motion. That is, if it requires a pull of 2 pounds to work the valve, the water level could change until the float had displaced about 1 pound of water (on account of the difference of leverage) before the valve could be moved. In reality the resistance is very small. There is no stuffing box on the valve stem, the supply pipe *O* being screwed to the valve in the place of its bonnet, and extended in height above the top of the standpipe so it can be left open. The chain *d*, then, can pass through the supply pipe and be attached directly to the valve stem. The pull now on the

chain necessary to raise the valve is very slight, as it has only to overcome the weight of the valve, which is very small, being submerged. The resistance of the shaft to turning is also very slight, as the boxes in which the shaft turns are provided with ball bearings. The resistance of the whole system is so small that the mechanism will hold the water level so nearly constant that no change of its level is perceptible in the gauge glasses. The necessity of holding this water level constant will be obvious later.

The water level can be set for any lift between 0 and 25 feet at intervals of $\frac{1}{4}$ of an inch, by placing the pall *c* in the different teeth of the gear *a*; the difference of a pair of teeth giving a difference of water level in the standpipe of about $\frac{1}{4}$ of an inch. The lift can be changed or set as follows: To decrease the lift, the balanced valve can be opened and made to admit more water by the handle *R* (Figure 1), which is on an arm of a bell-crank lever that is connected by a chain *S* (Figures 1 and 6) to an arm of the lever *b*, which operates the valve. To increase the lift, the standpipe can be split by opening the three-way cock *k* (Figure 3). This cock is operated through a system of levers and rods by the handle *P* (Figure 1). Now it is apparent that as the water level falls the float will turn the shaft of the regulating device to the right, and perhaps cause the balanced valve to admit water as fast or even faster than it is withdrawn. To prevent this, a second lever *e* (Figure 6) which carries a shield on one of its arms has been provided, and this shield, if the lever is swung to the left, will throw the pall out of the gear. Now the rod *f*, which works this lever, is attached to the same lever that operates the three-way cock *k*, so that the handle *P* (Figure 1) will throw out the pall *c* (Figure 6) before the three-way cock is opened, and the shaft will then be free to turn without moving the lever *b*.

The supply pipe *O* (Figure 3) is supplied with the feed water from the tank *T* (Figure 1). This water is admitted by the value *U* to the chamber *V*, which leads to the supply pipe *O*, through the drop-valve *W*. A gauge glass *X* gives the water level in the chamber *V*. The feed water tank *T* rests on scales and is weighed before beginning the test. As the injector must be running before the test is begun, a second supply is obtained through the pipe *Y*, this supply being governed by the valve *Z*.

A test is started as follows: Start the injector, supplying the standpipe through the pipe *Y* and valve *Z*. Have the three-way cock

H thrown down, the delivered water running to waste through the pipe *I*. Set the lift and weigh the empty delivery and overflow tanks, the feed water in tank *T* having been previously weighed. Now, at a preparatory signal (say 5 seconds before the start) close the valve *Z*. This shuts off the water supply, but the chamber *V* is large enough to take care of it until water can be drawn from the tank *T*. At the starting signal close the cock &, the three-way cock *H* being thrown at the same time. As these two motions are similar, there is no reason why two persons cannot make them at the same instant, which gives a correct start for both the suction and the delivered water. Throwing the three-way cock *H* sends the delivery water to the weighing tanks. Thus these weighing tanks receive no water until the test is begun, and it is taken from them in the same manner when the test is ended.

When the cock & is thrown it locks the water into the gauge glass *X*, and setting an index on this level, the amount of water in the chamber *V*, or in the whole system at the start of the test, is determined. After this index is set the cock & can be opened again, and water can be drawn from the tank *T*. Now if the test is stopped with the same amount of water in the chamber *V* as at the start, the amount of water drawn from the tank will be just the amount of suction water used, provided there remains in the whole system the same amount as at the start, which will be the case if the water level in the standpipe is the same.

To stop the test, with the same amount of water in the system as at the start, proceed as follows: At the preparatory signal, shut off the water supply from the tank *T* by closing the valve *U*, care being taken that the water level in the gauge glass *X* is not much above the index. Now at the final signal close the drop-gate valve *W*, the three-way cock *H* being thrown at the same instant. The valve *W*, being closed, has locked into the chamber *V* all water that it held at the end of the test, and now sufficient water can be drawn from the tank *T* to bring the level up to the index which was the water level in the chamber at the start of the test.

To insure no leakage by the valve *Z* during the test, a gate valve has been placed back of it. After the test is started this gate valve can be closed, and a drip cock between the two valves can be opened.

It is understood, of course, that observations have been taken throughout the test for the pressure of the steam, the pressure of

the delivery, the lift or suction, and the temperature of the suction, and the delivered water.

With this method of determining the amount of steam used by the difference in weight of the delivered and the suction water, great accuracy and precision are necessary, as an error of 1 per cent. in the determination of either the delivered or the suction water would result in an error of nearly 10 per cent. in the quantity of steam used. Hence, the necessity of employing the delicate mechanisms and the special devices that have been used in this apparatus is apparent

CONTRIBUTION FROM THE LABORATORY OF SANITARY CHEMISTRY.

I.

ON NITRITES AS A PRODUCT OF COMBUSTION.

BY EDWARD W. AXSON, M.A.

THE experiments here described were undertaken in continuation of the work of Mr. George Defren,[1] who showed that when pure water was left exposed in evaporating dishes to the air of rooms in which gas had been burning, the water so exposed gave when tested for nitrites, a reaction which varied in intensity approximately with the length of the exposure. Mr. Defren tried also a quantitative method similar to that ordinarily used for carbon dioxide in rooms, namely, drawing the air to be tested into 8-liter bottles, and absorbing the nitrites by introducing 100 cc. pure water, and allowing it to stand 12 hours.

The question of nitrites in the air has received a good deal of attention from various chemists, a brief account of whose work may be found in an article by Alfred von Bibra,[2] and a more complete list of references on the subject has been prepared by Mr. Defren in the article already referred to.

The main facts are as follows: Schönbein and Loew stated that active combustion was accompanied by the formation of ozone (in addition to carbon dioxide and water) which could be detected by its odor and by its reaction with starch and potassium iodide. Böke, however, disputed their assertions, claiming that the reactions observed were due to the higher oxides of nitrogen and not to ozone. W. V. Hoffmann showed that the gas so obtained was reddish in color, and had an odor like that of nitrous acid; and Zoeller and Greete proved conclusively, by burning purified hydrogen in purified air, that it was nitrous acid. Rubner and Cramer have made quantitative determina-

[1] *Technology Quarterly*, IX, Nos. 2 and 3, June and September, 1896.

[2] Archiv für Hygiene, 15, 216.

tions of this acid, using the ordinary methods of absorption by bubbling the products of combustion through some absorbent. Rubner used for this purpose a solution of barium hydrate contained in a Schlösing absorption apparatus, while Cramer employed pure water in a flask chilled with ice.

This subject derives its interest from the fact that the nitrites so formed are thought by many to be one of the causes of the headache and depression experienced in rooms artificially lighted and poorly ventilated.

The purpose of these experiments was to determine:

(1) Whether reliance could be placed in the common absorption flask methods when the gas to be absorbed was present in such minute quantities.

(2) What was the best absorbent to be used.

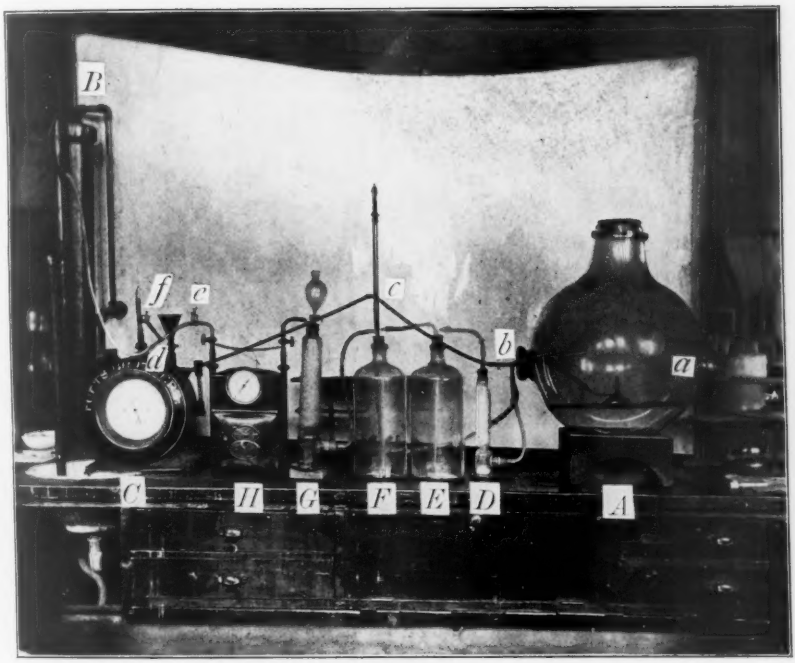
(3) If possible, in what form the gas is present.

(4) What substances, when burned, produce it most abundantly, and whether or not any is formed in the human system.

(5) If possible, what the effect would be of breathing it in considerable quantities.

The apparatus used in these determinations is shown in the accompanying cut.

A is a large 60-liter glass balloon; air enters at *a*, gas enters through one tube at *b*, and the products of combustion are drawn off through another at the same place. *B* is a Richards pump to provide suction. The main current of air passes through the tube *c* to the gas meter *C*, emerging from the latter at *d*. The portion of air to be tested is drawn off from the main current at *b* by means of a T tube, and passes up through the calcium chloride tower *D* which removes the moisture and prevents the excess of nitrites which would occur if condensation took place in the first bottle, *E*. Thence it passes through the two clean, dry, 4-liter bottles *E* and *F*, and up through the absorption flask *G*, filled with glass beads and containing the absorbent to be used. From the flask it passes through the second meter *H*, which registers the volume of air passing through the absorption apparatus, and finally joins the main current again at the T tube *d*, through which it is drawn off. In this way one pump is made to supply suction for both circuits, the amount of air passing through each being regulated by means of the two pinch cocks *e* and *f*. When



Apparatus for Testing the Efficiency of Absorption Tubes.

gas was the fuel, we used the small Bunsen burner shown in the cut, while for kerosene or alcohol we placed little lamps on the shelf shown in the balloon. The calcium chloride tower was found to remove a little of the nitrites along with the moisture, but it was necessary to prevent condensation in the bottles, and moreover the error it introduced was the same in all cases, so that it did not affect the comparative values of the results obtained. After the run, the two bottles were removed, 100 cc. of the absorbent to be used was introduced, and the bottle shaken occasionally and left at least 24 hours, sometimes 48. To secure as complete absorption as possible, the bottles were usually rinsed quickly with ammonia-free water, and the absorption process repeated, though the amounts of nitrites and ammonia so obtained were seldom very considerable. Of the absorbent used, one-half (50 cc.) was employed for the determination of nitrites by the Griess method, while the second half was tested for NH_3 with Nessler's reagent.[1] The standard solutions used for comparison contained, for nitrites .0000001 gram. N per cc.; for NH_3 .00001 gram. NH_3 per cc. When water was used as the absorbent, it was freed from ammonia by redistilling over potassium permanganate. The sodium hydrate used was obtained free from nitrites by dissolving metallic sodium. The strength of the latter usually employed was $\frac{N}{40}$. The air used was taken directly from the laboratory, but the room was not in use for other purposes at the time, and by a special test, in which the number of burners lighted rendered the air worse than it was at the time of any experiment, it was shown that the amounts of nitrites and ammonia obtained from that source were negligible when compared with those obtained in the course of an experiment.

Following is a condensed table of some of the results:

[1] Whenever NaOH was used as the absorbent in the flask, a milkiness resulted on adding the Nessler reagent, making it necessary to distil over the free ammonia before it could be read. The cause of this milkiness was not determined.

No.	Fuel.	Rate of total air passed. (Cu. ft. per hour.)	Calculated from Bottles.		Bottle No. 1.				Bottle No. 2.			
			Total nitrites formed per hour.	Total NH_3 formed per hour.	Absorbent.	Nitrites per cu. m. of air passed.	NH_3 per cu. m. of air passed.	Nitrites per cu. m.: NH_3 per cu. m.	Absorbent.	Nitrites per cu. m. of air passed.	NH_3 per cu. m. of air passed.	Nitrites per cu. m.: NH_3 per cu. m.
1	Gas, non-luminous . . .	24.534	.000917	.00809	H_2O	.00134	.0239	1 : 17.6	...	.....	.....	.....
2	Gas, non-luminous . . .	22.880	.000784	.00676	H_2O	.00123	.0053	1 : 4.3	H_2O	.00253	.0016	1 : 0.6
3	Gas, non-luminous . . .	15.194	.000880	.00024	$Ba(OH)_2$	.00187	....	.....	H_2O	.00208	.0016	1 : 0.5
4	Gas, non-luminous . . .	13.596	.001000	.00204	$NaOH(\frac{N}{16})$	.00264	.0058	1 : 2.0	H_2O	.00240	.0026	1 : 1.1
5	Kerosene	21.234	.001140	.00338	$NaOH(\frac{N}{80})$	.00194	.0058	1 : 2.9	H_2O	.00184	.0042	1 : 2.2
6	Kerosene	20.803	.001110	.00270	$NaOH(\frac{N}{40})$	.00192	.0047	1 : 2.4	H_2O	.00186	.0047	1 : 2.5
*7	Kerosene	20.428	.001330	.00151	NaOH	.00233	.0026	1 : 1.1	H_2O	.00119	.0026	1 : 2.2
*8	Kerosene	19.104	.001180	.00141	NaOH	.00223	.0026	1 : 1.2	H_2O	.00109	.0021	1 : 1.9
9	Alcohol	....	.....	....	Alcohol.	.00074	....	.....	H_2O	.00106	.0074	1 : 7.0
*10	Alcohol	22.550	.001300	.00464	$NaOH(\frac{N}{40})$	.00209	.0074	1 : 3.5	H_2O	.00151	.0079	1 : 5.2
*11	Alcohol	22.810	.001580	.00469	NaOH	.00185	.0074	1 : 4.0	H_2O	.00131	.0079	1 : 5.9
12	Alcohol	18.476	.001170	.00380	NaOH	.00227	.0074	1 : 3 2	H_2O	.00134	.0074	1 : 5.5
13	Gas, luminous	28.586	.001990	.00370	NaOH	.00250	.0047	1 : 1.7	H_2O	.00194	.0063	1 : 3.3
14	Gas, luminous	16.130	.001100	.00119	NaOH	.00247	.0026	1 : 1.0	H_2O	.00212	.0032	1 : 1.4
15	Kerosene	31.492	.001920	.00324	NaOH	.00219	.0037	1 : 1.6	H_2O	.00184	.0032	1 : 1.7

*Tests made at the end of successive half hours.

The results obtained seem to show:

(1) That absorption flask methods are unreliable for determining nitrites when present in the extremely small quantities in which they occur in the air. The amounts obtained from the flask varied widely, and averaged only about one-tenth that obtained from the bottles, one-third being the maximum for the ordinary rate of bubbling at the ordinary temperature. An evaporating dish containing 100 cc. H_2O, and placed in the balloon during the first experiments, collected more nitrites in proportion to the volume of absorbent, than the water used in the absorption flask.

(2) That dilute NaOH is a better absorbent than pure water or alcohol.

(3) That ammonium nitrite is probably not present *as such*. This is indicated by the widely varying ratios of nitrites per cubic meter to NH_3 per cubic meter, which in most of the cases observed is very different from the theoretical ratio 1 : 1.25; and also by the difficulty of absorption. Since ammonium nitrite is a substance readily soluble in water, this difficulty of absorption would seem to indicate either that it is not formed at all in such combustions, or else that if it is formed it at once undergoes dissociation, and N_2O_3 is perhaps changed to some higher oxide of nitrogen which fails to give the Griess reaction. As evidence of the possibility of such oxidation may be mentioned the fact that Berthelot, Stohmann, Rubner and others, found nitrates as well as nitrites in the absorption liquid, though the only two tests made for nitrates in the course of these experiments failed to detect more than a trace. In order to determine if such dissociation was increased by standing, two bottles were allowed to stand 48 hours before introducing the absorbent, but no perceptible difference was found.

(4) That for the same height of flame, kerosene and alcohol give approximately the same amount of nitrites per hour (experiments 8 and 12), while both kerosene and alcohol produce decidedly more than gas when burned under the same conditions (experiments 2, 5, and 11). Gas when burned with a luminous flame seems to produce slightly more than when burned with a non-luminous. In the case of ammonia the results were not so uniform, but apparently the relations are different, gas producing decidedly more than alcohol (experiments 2 and 11), and alcohol slightly more than kerosene (experiments 8 and 12), while a non-luminous gas flame produces more than a luminous

(experiments 1 and 13). As a rule, increasing the supply of air by applying more suction had the effect of increasing the total amounts of both nitrites and ammonia formed in a given time.

The lack of uniformity in these results is probably to be explained by slight variations in the amounts of fuel consumed, for while we endeavored in all cases to have the flames the same height ($1\frac{1}{2}$ inches), slight variations were unavoidable, and no measurement was made of the gas, etc., burned.

The determination of nitrites in the exhaled breath was accomplished by breathing for 1 hour through a 4-liter bottle which contained 100 cc. dilute NaOH, and was shaken constantly. The test was made out of doors, and a small flask was used as a trap for saliva, which reacts quite strongly for nitrites, derived possibly from the exhaled breath. The NaOH when tested showed a considerable quantity of both nitrites and ammonia; a rough calculation of the volume of breath exhaled showing .00028 grams N as nitrite, and .0169 grams NH_3 per cubic meter. A blank test made on the same air by drawing about the same volume through another bottle showed only .000004 grams N as nitrite, and .00006 grams NH_3 per cubic meter, apparently indicating the formation of both substances in the metabolic processes of the body.

(5) In order to test the physiological effects of breathing the nitrites formed in combustion, use was made of a large air-tight box ($7 \times 6\frac{1}{2} \times 4$ feet) which had been employed in previous experiments on carbon dioxide. In this the writer remained 2 hours while the products of combustion from a large Erlenmeyer gas burner placed under an asbestos hood were drawn through. In order to remove as much of the carbon dioxide as possible, the air before entering the box was passed rapidly through an absorption tower containing strong sodium hydrate. This served to remove a large part of the carbon dioxide for the first hour as shown by the following tests made within the box by means of a Fitz apparatus, the first one being made at the beginning of the test:

Time. P. M.	Parts CO_2 per 10000.
1.40	6
2.00	10
2.35	17
3.00	>28

By 3.00 P. M. the NaOH had become exhausted and the CO_2 rose above the amount measurable with the Fitz apparatus.

Fifteen minutes after entering the box a feeling of discomfort was experienced, accompanied by slight perspiration, which at the end of half an hour had increased to decided depression and profuse perspiration. After 45 minutes I felt drowsy and listless, and noticed a slight headache which afterwards disappeared. A smarting of the eyes was felt after an hour and a half, which, together with excessive perspiration, continued till the end. The results of this test were not conclusive, inasmuch as the sodium hydrate took out part of the nitrites, as was shown by the strong reaction obtained from it afterwards, and did not remove all the carbon dioxide. There remained, however, a considerable quantity of nitrites in the air entering the box, as was shown by testing some of the water of condensation which collected on a bottle of ice water placed within, and also by testing a sample of the air drawn out through a bottle. The latter showed .00111 grams N as nitrite per cubic meter. Most of the discomfort experienced seemed to be due to the excessive moisture and high temperature, since on fanning it temporarily disappeared. A subsequent test made with the same burner showed the ratio of nitrites to CO_2 present to be 1 : 2243.

The writer desires to acknowledge his indebtedness to Mrs. E. H. Richards, at whose suggestion and under whose supervision the above experiments were made, and to Dr. C. A. Meserve and Mr. A. G. Woodman for much kind assistance.

RESULTS OF TESTS MADE IN THE ENGINEERING LABORATORIES.

XI.

Applied Mechanics.

Aluminum Tests.

The specimens tested were sent by the Pittsburgh Reduction Company. No chemical analysis of the specimens was made, but they are presumably nearly pure aluminum.

TENSION TESTS ON ALUMINUM WIRE.

Number of test.	Date, 1898-99.	Diameter of cross section. (Ins.)	Area of cross section. (Sq. ins.)	Gauged length. (Ins.)	Limits of loads used for calculation of modulus of elasticity. (Lbs.)	Elastic elongation for difference of loads used in calculation of modulus of elasticity. (Ins.)	Modulus of elasticity. (Lbs. per sq. in.)
1	Oct. 25	0.1281	0.0129	50.0	20 — 120	0.0403	9,630,000
2	Oct 31	0.1278	0.0128	50.0	70 — 160	0.0396	8,860,000
3	Nov. 1	0.1279	0.0129	50.0	125 — 200	0.0300	9,730,000
4	Nov. 3	0.1281	0.0129	50.0	25 — 125	0.0438	8,860,000
5	Nov. 8	0.1281	0.0129	50.0	25 — 125	0.0412	9,420,000
6	Nov. 10	0.1280	0.0129	50.0	25 — 125	0.0406	9,570,000
7	Nov. 14	0.1282	0.0129	50.0	25 — 125	0.0441	8,800,000
8	Nov. 21	0.1278	0.0128	50.0	50 — 150	0.0369	10,600,000
9	Dec. 1	0.1280	0.0129	50.0	25 — 125	0.0362	10,700,000
10	Dec. 6	0.1281	0.0129	50.0	25 — 125	0.0363	10,700,000
11	Dec. 7	0.1283	0.0129	50.0	75 — 195	0.0496	9,360,000
12	Dec. 12	0.1282	0.0129	50.0	25 — 125	0.0394	9,830,000
13	Dec. 13	0.1281	0.0129	50.0	25 — 125	0.0368	10,600,000
14	Dec. 14	0.1280	0.0129	50.0	50 — 175	0.0496	9,790,000

TENSION TESTS ON ALUMINUM WIRE. — *Concluded.*

Number of test.	Date, 1898–99.	Elastic limit. (Lbs.)	Elastic limit. (Lbs. per sq. in.)	Maximum load. (Lbs.)	Maximum load. (Lbs. per sq. in.)	Area of fractured section. (Sq. in.)	Reduction of area. (Per cent.)	Ultimate extension in 48 inches.	Ultimate extension. (Per cent.)
1	Oct. 25	200	15,500	343	26,600	0.00229	82.2	0.31	0.65
2	Oct. 31	160	12,500	337	26,300	0.00212	83.4	....	....
3	Nov. 1	240	18,700	345	26,900	0.00251	80.5	0.31	0.65
4	Nov. 3	225	17,500	336	26,100	0.00246	80.9	....	....
5	Nov. 8	195	15,100	340	26,400	0.00264	79.5	0.26	0.52
6	Nov. 10	225	17,500	338	26,300	0.00274	78.7	....	....
7	Nov. 14	225	17,400	336	26,000	0.00302	76.6	0.15	0.30
8	Nov. 21	245	19,100	331	25,800	0.00174	86.5	....	....
9	Dec. 1	225	17,500	346	26,900	0.00181	85.9	....	....
10	Dec. 6	225	17,500	338	26,200	0.00322	75.0	0.31	0.62
11	Dec. 7	225	17,400	336	25,900	0.00221	82.9	0.27	0.54
12	Dec. 12	235	18,200	347	26,900	0.00270	79.1	0.51	1.02
13	Dec. 13	225	17,500	347	26,900	0.00255	80.2	....	....
14	Dec. 14	225	17,500	346	26,900	0.00258	80.0	0.46	0.92

TORSION TEST ON ALUMINUM ROD. (SERIES 1.)

Number of test.	Date, 1898.	Diameter of specimen. (Ins.)	Length between jaws. (Ins.)	Maximum twisting moment. (In. lbs.)	Number of turns between jaws.	Apparent outside fiber stress. (Lbs. per sq. in.)	Average number of turns per inch.
1	Oct. 26	0.2572	12.0	57.0	40.4	17,100	3.37
2	Oct. 26	0.2567	12.0	53.0	25.0	15,900	2.08
3	Oct. 29	0.2571	12.0	59.2	32.8	17,700	2.73
4	Oct. 29	0.2559	12.0	60.4	35.7	18,300	2.98
5	Nov. 2	0.2568	12.0	68.1	43.8	17,500	3.65
6	Nov. 4	0.2571	12.0	58.0	18.9	17,400	1.58
7	Nov. 4	0.2576	12.0	58.8	23.8	17,500	1.98
8	Nov. 7	0.2564	12.0	58.8	47.3	17,800	3.94
9	Nov. 9	0.2557	12.0	56.0	27.9	17,000	2.33
10	Nov. 11	0.2566	12.0	58.2	40.7	17,600	3.39

TORSION TESTS ON ALUMINUM ROD. (SERIES 2.)

Number of test.	Date, 1898.	Diameter of specimen. (Ins.)	Length between jaws. (Ins.)	Maximum twisting moment. (In. lbs.)	Number of turns between jaws.	Apparent outside fiber stress. (Lbs. per sq. in.)	Average number of turns between jaws, per inch.
1	Nov. 2	0.3668	12.0	179.5	24.1	18,500	2.01
2	Nov. 7	0.3665	12.0	185.4	23.9	19,200	1.99
3	Nov. 9	0.3669	12.0	181.7	25.8	18,700	2.15
4	Nov. 11	0.3674	12.0	180.9	24.4	18,600	2.03
5	Nov. 14	0.3668	12.0	177.9	31.7	18,400	2.64
6	Nov. 16	0.3669	12.0	178.2	26.8	18,400	2.23
7	Nov. 21	0.3668	12.0	180.0	23.5	18,600	1.96
8	Nov. 23	0.3666	12.0	184.0	14.4	19,000	1.20
9	Nov. 28	0.3669	12.3	181.2	26.4	18,700	2.17
10	Dec. 1	0.3669	12.0	182.4	23.9	18,800	1.94

TORSION TESTS ON ALUMINUM ROD. (SERIES 3.)

Number of test.	Date, 1898.	Diameter of specimen. (Ins.)	Distance between jaws.	Maximum twisting moment. (In. lbs.)	Number of turns between jaws.	Apparent outside fiber stress. (Lbs. per sq. in.)	Average number of turns per inch.
1	Nov. 14	0.4590	12.0	398.7	12.2	21,000	1.02
2	Nov. 16	0.4590	12.0	395.2	12.3	20,800	1.03
3	Nov. 21	0.4588	12.0	398.6	11.5	21,000	0.96
4	Nov. 23	0.4589	12.0	400.4	10.5	21,100	0.87
5	Nov. 28	0.4589	12.1	405.0	11.9	21,300	0.99
6	Dec. 1	0.4588	12.0	399.3	12.7	21,100	1.06
7	Dec. 5	0.4586	12.0	399.2	12.2	21,100	1.02
8	Dec. 5	0.4587	12.1	402.7	11.5	21,200	0.95
9	Dec. 9	0.4588	12.0	395.3	11.7	20,800	0.97
10	Dec. 12	0.4590	12.0	393.1	11.9	20,700	0.99
11	Dec. 14	0.4588	12.0	407.6	12.2	21,500	1.02

TORSION TESTS ON ALUMINUM TUBE. (SERIES 1.)

Number of test.	Date, 1899.	External diameter of specimen. (Ins.)	Internal diameter of specimen. (Ins.)	Length of specimen between jaws. (Ins.)	Maximum twisting moment. (In. lbs.)	Number of turns between jaws.	Apparent outside fiber stress. (Lbs. per sq. in.)	Average number of turns per inch.
1	Jan. 2	0.2513	0.1470	12.0	53.6	14.22	19,500	1.19
2	Jan. 2	0.2519	0.1484	12.0	50.6	17.5	18,300	1.46
3	Jan. 6	0.2515	0.1529	12.0	52.0	17.1	19,300	1.43
4	Mar. 30	0.2571	0.1473	10.0	58.0	4.2	19,500	0.42
5	Mar. 30	0.2515	0.1473	12.0	48.6	17.6	17,600	1.47
6	Mar. 30	0.2515	0.1473	13.0	48.2	6.2	17,500	0.52
7	Mar. 31	0.2550	0.1500	12.0	54.0	17.6	19,600	1.47
8	Mar. 31	0.2513	0.1500	12.0	51.0	15.7	18,700	1.31

TORSION TESTS ON ALUMINUM TUBE. (SERIES 2.)

Number of test.	Date, 1898–9.	External diameter. (Ins.)	Internal diameter. (Ins.)	Distance between jaws. (Ins.)	Maximum twisting moment. (In. lbs.)	Number of turns between jaws.	Apparent outside fiber stress. (Lbs. per sq. in.)	Average number of turns per inch.
1	Dec. 14	0.3750	0.2772	12.0	97.5	8.65	13,400	0.72
2	Dec. 16	0.3749	0.2754	13.0	84.9	7.15	11,600	0.55
2	Dec. 19	0.3756	0.2772	12.0	97.3	7.2	13,300	0.60
4	Dec. 23	0.3749	0.2775	12.0	85.1	2.7	11,800	0.23
5	Dec. 30	0.3735	0.2776	12.0	74.0	0.70	10,100	0.06
6	Jan. 2	0.3743	0.2755	12.0	73.9	4.00	10,300	0.33
7	Jan. 2	0.3739	0.2769	12.0	77.2	2.29	10,800	0.19
8	Jan. 6	0.3751	0.2788	12.0	85.0	8.0	11,800	0.67
9	Jan. 11	0.3753	0.2983	12.0	76.0	3.4	12,200	0.28
10	Jan. 11	0.3750	0.2772	13.0	93.8	6.3	12,900	0.53

TORSION TESTS ON ALUMINUM TUBE. (SERIES 3.)

Number of test.	Date, 1898-9.	External diameter of specimen. (Ins.)	Internal diameter of specimen. (Ins.)	Length between jaws. (Ins.)	Maximum twisting moment. (In. lbs.)	Number of turns between jaws.	Apparent outside fiber stress. (Lbs. per sq. in.)	Average number of turns between jaws.
1	Dec. 16	0.5007	0.3688	13.5	341.0	9.5	19,500	0.70
2	Dec. 19	0.5007	0.3623	12.0	329.6	4.45	18,400	0.37
3	Dec. 23	0.5019	0.3634	12.0	371.0	7.05	20,600	0.59
4	Dec. 30	0.5002	0.3631	12.0	340.0	6.8	19,200	0.57
5	Jan. 11	0.5011	0.3661	12.0	365.7	7.0	20,700	0.53
6	Jan. 11	0.5009	0.3645	12.0	352.0	6.0	20,000	0.50
7	Mar. 2	0.5011	0.3635	12.0	323.7	9.8	18,100	0.82
8	Mar. 2	0.5009	0.3625	10.0	366.1	1.83	20,600	0.18
9	Mar. 2	0.5012	0.3638	12.0	348.3	9.3	19,500	0.78
10	Mar. 4	0.5007	0.3632	12.0	330.5	9.9	18,500	0.83

PHOSPHOR BRONZE.

TORSION TESTS UPON PHOSPHOR BRONZE ROD.

Date, 1899.	Diameter of cross section. (Ins.)	Length of specimen between jaws. (Ins.)	Maximum twisting moment. (In. lbs.)	Number of turns between jaws.	Apparent outside fiber stress. (Lbs. per sq. in.)	Average number of turns per inch.
Mar. 6	0.2506	9.6	254.9	10.28	82,500	1.08
Mar. 6	0.2507	7.9	254.4	9.7	82,100	1.22
Mar. 7	0.2509	7.0	263.5	9.59	84,900	1.37
Mar. 7	0.2503	8.0	256.0	9.54	83,100	1.19
Mar. 11	0.2505	8.0	256.0	10.77	82,900	1.35
Mar. 11	0.2505	8.0	261.3	10.73	84,700	1.34
Mar. 11	0.2505	8.0	242.9	8.2	78,600	1.03
Mar. 13	0.2504	8.0	255.0	....	82,700	....
Mar. 13	0.2505	8.0	264.0	10.5	85,500	1.29
Mar. 14	0.2508	8.0	261.0	7.46	84,300	0.93
Mar. 14	0.2510	8.0	269.0	12.0	86,700	1.50
Mar. 16	0.2506	8.0	258.5	6.1	83,700	0.76
Mar. 16	0.2506	8.0	254.4	8.1	82,400	1.01
Mar. 21	0.2507	8.0	251.0	8.6	81,000	1.08
Mar. 23	0.2509	8.0	252.0	11.9	81,200	1.49
Mar. 23	0.2507	8.0	240.0	7.4	77,500	0.93
Mar. 25	0.2506	13.0	247.0	17.0	80,000	1.31
Mar. 25	0.2510	8.0	250.2	9.82	80,600	1.23
Mar. 28	0.2504	8.0	248.7	....	80,700	....
Mar. 28	0.2508	8.0	249.3	9.1	80,500	1.14

NOTE. — These tests were made upon ordinary phosphor bronze round rod. The surface was nicely finished. The diameter at different portions of the rod did not vary more than 0.001 inch.

TORSION TESTS ON COLD ROLLED STEEL SHAFTING $1\frac{11}{16}$″ DIAMETER. (From Jones & Laughlin's.)

Number of test.	Date, 1898-9.	Diameter of cross section. (Ins.)	Distance between jaws. (Ins.)	Gauged length. (Ins.)	Elastic limit. (In. lbs.)	Outside fiber stress at elastic limit. (Lbs. per sq. in.)	Maximum twisting moment. (In. lbs.)	Apparent outside fiber stress as calculated from maximum twisting moment. (Lbs. per sq. in.)	Limits of loads for calculating shearing modulus of elasticity. (In. lbs.)	Angle of twist for difference of loads used in calculating shearing modulus of elasticity.	Shearing modulus of elasticity. (Lbs. per sq. in.)	Number of turns between jaws at fracture.	Turns per foot between jaws at fracture.
										° ′ ″			
1	Dec. 17	1.684	71.8	48.0	36,400	38,800	77,760	82,900	1800 — 7200	1 34 30	11,900,000	11.00	1.84
2	Dec. 17	1.686	71.8	48.0	34,200	36,400	68,490	72,800	3600 — 9000	1 35 10	11,800,000	10.71	1.79
3	Mar. 2	1.686	71.0	48.0	30,870	32,800	67,230	71,500	1800 — 7200	1 34 10	12,000,000	12.21	2.06
4	Mar. 7	1.686	71.2	48.0	34,200	36,400	70,560	75,000	1800 — 7200	1 33 20	12,000,000	9.97	1.58
5	Mar. 8	1.686	71.0	48.0	34,200	36,400	71,190	75,700	1800 — 7200	1 33 30	12,000,000	9.48	1.60
6	Mar. 9	1.686	71.0	48.0	30,600	32,500	66,510	70,700	1800 — 7200	1 34 00	12,000,000	11.65	1.97
7	Mar. 14	1.686	71.4	48.0	32,400	34,400	68,850	73,200	1800 — 7200	1 32 30	12,000,000	11.30	1.90
8	Mar. 16	1.687	71.2	45.8	32,400	34,400	68,670	72,800	1800 — 7200	1 30 50	11,800,000	11.26	1.90
9	Mar. 18	1.686	71.1	48.0	32,400	34,400	68,850	73,200	1800 — 7200	1 34 20	11,900,000	10.74	1.81
10	Mar. 20	1.687	71.1	48.0	32,400	34,300	71,100	75,300	1800 — 7200	1 33 30	12,000,000	10.49	1.77
11	Mar. 25	1.685	71.2	48.0	30,600	32,500	69,060	73,400	1800 — 7200	1 33 00	12,100,000	10.15	1.71
12	Apr. 1	1.684	71.4	48.0	30,600	32,600	66,370	70,800	1800 — 7200	1 35 40	11,800,000	10.42	1.75

TRANSVERSE TESTS UPON SPRUCE BEAMS.

Number of test.	Date, 1898.	Width and depth of specimen. (Ins.)	Distance between supports. (Feet.)	Limits of loads for calculation of modulus of elasticity. (Lbs.)	Deflection for difference of loads used in calculation of modulus of elasticity. (Ins.)	Modulus of elasticity. (Lbs. per sq. in.)	Breaking load. (Lbs.)	Weight of beam. (Lbs.)	Modulus of rupture. (Lbs. per sq. in.)	Maximum intensity of longitudinal shear. (Lbs. per sq. in.)	Manner of Failure.
616	Oct. 15	$3\frac{7}{8}'' \times 12\frac{1}{8}''$	15	500 — 5,000	0.6906	1,380,000	11,410	181	5,400	182	Broke by crushing.
617	Oct. 17	$4'' \times 12''$	15	500 — 4,500	0.6073	1,400,000	12,990	165	6,080	203	Broke by crushing.
618	Oct. 18	$3\frac{7}{8}'' \times 12\frac{1}{8}''$	15	500 — 6,500	0.8881	1,430,000	12,600	173	5,960	201	Broke by crushing.
619	Oct. 21	$3\frac{3}{4}'' \times 12''$	15	500 — 6,500	0.9244	1,460,000	13,490	166	6,730	225	Broke by tension.
621	Nov. 1	$3\frac{7}{8}'' \times 12\frac{1}{4}''$	15	500 — 4,500	0.6886	1,190,000	12,510	153	5,850	199	Broke by tension.
622	Nov. 14	$3\frac{7}{8}'' \times 12\frac{1}{8}''$	15	500 — 4,500	0.8169	1,030,000	9,825	145	4,690	159	Broke by tension near a knot.

Note. — Beams were loaded at the center of span. The timber was of good quality and fairly well seasoned.

Rope Tests.

TESTS UPON COTTON ROPE $\frac{7}{8}''$ DIAMETER.

The tests upon rope the past year have been made with several objects in view. It was desired to obtain the relative holding power of various kinds of knots, the relative efficiency of various knots for uniting two ends of a rope, the stretch of a rope under a gradually increasing load, and the maximum tensile strength of the rope in question. A grade of white cotton rope $\frac{7}{8}$ of an inch in diameter was selected for a series of tests. The two coils used contained about 700 feet in all. The series of knots tested for holding power is illustrated in a former report of rope tests. (See page 392, Vol. X, No. 4, *Technology Quarterly*.) The knots used in tying the ends of the rope together are illustrated by Figures 1–5.

The apparatus used for measuring the stretch of the rope was adjusted at an initial load of 20 pounds, and readings of stretch taken as the load was gradually increased. As the stretch depends to a certain extent on the time the specimen is under load, records of the time required to reach the maximum load were kept. The breaking load was reached in the case of the cotton rope in about 20 minutes; in the case of the manila rope in about 10 minutes.

Considerable difficulty was experienced in fastening the ends of the cotton rope to the testing machine in such a way as to get the break to come in the central part of the specimen. Eye splices which serve for manila, hemp and sisal would not answer in the case of cotton rope. A number of methods of holding were tried with poor success, the rope invariably breaking at the knot at one of the holders. The timber hitch has been found by previous tests on other kinds of rope to give an efficiency of about 76 per cent.

For purposes of comparison it was assumed that cotton rope fastened in this way to the testing machine gave at failure 76 per cent. of the true strength, which would appear to be about 4,420 pounds. Upon this basis the efficiencies given in the table were calculated.

MANILA ROPE TESTS.

The following tests were made in much the same manner upon manila rope. The rope was 2 inches in circumference and was taken from one large coil. The maximum strength was obtained without difficulty from the specimens held at the ends by eye splices. Tests were made also on $6''$ manila rope.

FIG. 1. — SQUARE KNOT.

FIG. 2. — OPEN HAND KNOT.

FIG. 3. — WEAVER'S KNOT.

FIG. 4. — ENGLISHMAN'S TIE.

FIG. 5. — ORDINARY TIE.

COTTON ROPE TESTS.

Number of test.	Date, 1898–9.	Number of feet per pound.	Number of turns of one strand per foot.	Maximum load. (Lbs.)	Average strength. (Lbs.)	Efficiency of knot. (Per cent.)	Method of Holding.
1	Oct. 26	6.67	6	3,470			
2	Nov. 7	4.91	6	2,960			
3	Dec. 5	6.00	6	3,920			Timber hitch knots at both ends, tied over 2-inch pipe couplings.
4	Dec. 14	6.00	6	3,620	3,360	76	
5	Dec. 14	5.52	6	3,190			
6	Mar. 4	5.11	5½	3,020			
7	Dec. 1	7.25	6	3,890			
8	Nov. 2	6.52	6	2,820			
9	Nov. 9	6.95	6	3,090			Slip knots at both ends, tied over 2-inch pipe couplings.
10	Dec. 14	5.52	6	3,740	3,430	78	
11	Jan. 4	5.77	..	3,620			
12	Nov. 4	....	6	2,550			
13	Nov. 7	5.00	6	3,100			
14	Dec. 1	7.25	6	3,920			Double half hitch knots at both ends, tied over 2-inch pipe couplings.
15	Dec. 12	6.13	6	3,440	3,380	76	
16	Dec. 30	6.75	6	3,870			
17	Nov. 21	4.76	6	2,570			
18	Oct. 24	4.56	5⅝	2,970			
19	Oct. 26	6.13	6	2,400			Bowline knots, tied over iron eyes.
20	Dec. 9	5.72	6	2,580	2,680	61	
21	Dec. 19	....	6	2,880			
22	Oct. 24	4.69	5⅝	2,140			
23	Nov. 4	4.70	6	2,210			
24	Nov. 21	4.70	6	2,090			Flemish loop knots, tied over iron eyes.
25	Dec. 12	5.50	6	2,120	2,170	49	
26	Dec. 21	5.52	6	2,270			
27	Nov. 14	6.29	..	2,520			
28	Nov. 21	4.89	6	2,280			Englishman's tie at center of rope. Ends tied in timber hitch knots over 2-inch pipe couplings.
29	Dec. 9	5.50	6	2,460	2,410	55	
30	Jan. 2	6.75	..	2,370			
31	Nov. 10	6.38	5½	2,380			
32	Nov. 16	4.89	5⅝	2,200			Square knot at center of rope. Ends tied in timber hitch knots over 2-inch pipe couplings.
33	Dec. 5	....	6	2,470	2,330	53	
34	Dec. 12	5.50	6	2,270			
35	Nov. 10	6.00	5½	2,120			
36	Nov. 16	4.89	5⅝	1,700			Weaver's knot at center of rope. Ends tied in timber hitch knots over 2-inch pipe couplings.
37	Dec. 19	5.50	6	2,460	2,090	47	
38	Dec. 21	5.50	6	2,090			
39	Nov. 14	6.29	5⅝	1,930			
40	Nov. 21	4.68	6	2,150	2,110	48	Open hand knot at center of rope. Ends tied in timber hitch knots over 2-inch pipe couplings.
41	Dec. 12	5.50	6	2,240			

NOTE. — The cotton rope was ¾ of an inch in diameter. All specimens in the knot tests were tested in a dry condition. The length of the specimen between holdings was about 4 feet. In the tests upon holding power the specimens all broke at one of the end knots. In the tests upon center knots the specimens all broke in the twists of the center knots.

TENSION TESTS ON 2″ MANILA ROPE. (3 strands.)

Number of test.	Date.	Number of feet per pound.	Number of turns of one strand per foot.	Condition.	Location of break.	Maximum load.	Average strength. (Lbs.)	Efficiency of knot or splice. (Per cent.)	Kind of knots or splices used.
1	Apr. 7, 1898	7.4	5½	Splices wet. Center of rope dry.	At center.	4,500	4,760	100	Eye splices at ends over iron eyes.
2	Apr. 12, 1898	...	6		At center.	4,800			
3	Apr. 14, 1898	7.8	6		At center.	4,910			
4	Apr. 23, 1898	...	..		At center.	4,810			
5	Dec. 3, 1897	7.4	6	Dry.	Upper knot.	3,290	3,140	66	Timber hitches at ends over 2″ pipe couplings.
6	Dec. 4, 1897	7.4	5½		Lower knot.	3,090			
7	Dec. 20, 1897	...	6		Lower knot.	3,040			
8	Dec. 9, 1897	7.1	6	Dry.	Lower knot.	2,890	2,840	60	Bowlines at ends over iron eyes.
9	Dec. 21, 1897	8.0	6		Upper knot.	2,670			
10	Jan. 1, 1898	7.3	6		Upper knot.	2,490			
11	Mar. 31, 1898	7.8	6		Lower knot.	2,720			
12	Mar. 31, 1898	...	6		Upper knot.	3,140			
13	Apr. 6, 1898	...	..		Lower knot.	3,140			
14	Dec. 21, 1897	7.7	6	Dry.	Upper knot.	1,930	2,090	44	Flemish loops at ends over iron eyes.
15	Jan. 1, 1898	7.0	6		Upper knot.	1,910			
16	Mar. 29, 1898	...	6½		Lower knot.	2,160			
16a	Mar. 29, 1898	7.5	5½		Lower knot.	2,340			
17	Oct. 13, 1897	...	6	Dry.	Middle knot.	3,540	2,910	61	Joined at middle with Englishman's knot. Held at ends with timber hitches.
18	Oct. 15, 1897	7.4	5½		Middle knot.	3,160			
19	Oct. 20, 1897	7.2	6		Middle knot.	2,750			
20	Oct. 29, 1897	...	6		Middle knot.	3,290			
21	Nov. 3, 1897	...	6½		Middle knot.	2,250			
22	Nov. 5, 1897	...	6		Middle knot.	2,680			
23	Dec. 9, 1897	7.1	6½		Middle knot.	2,730			
24	Dec. 8, 1897	7.0	6	Dry.	Middle knot.	2,910	2,700	57	Joined at middle with ordinary tie. Held at ends with timber hitches.
25	Dec. 8, 1897	7.0	6		Middle knot.	2,860			
26	Dec. 8, 1897	7.0	6		Middle knot.	2,780			
27	Dec. 8, 1897	7.5	6		Middle knot.	2,540			
28	Dec. 9, 1897	7.5	6		Middle knot.	2,410			
29	Oct. 13, 1897	7.0	6	Dry.	Middle knot.	2,530	2,480	52	Joined at middle with square knot. Held at ends with timber hitches.
30	Oct. 18, 1897	7.4	6		Middle knot.	2,300			
31	Oct. 27, 1897	7.3	6		Middle knot.	2,670			
32	Oct. 29, 1897	...	6		Middle knot.	2,450			
33	Nov. 5, 1897	...	6		Middle knot.	2,680			
34	Nov. 9, 1897	...	6		Middle knot.	2,220			
35	Oct. 11, 1897	...	6	Dry.	Middle knot.	2,370	2,180	46	Joined at middle with open hand knot. Held at ends with timber hitches.
36	Oct. 3, 1897	7 0	6		Middle knot.	2,310			
37	Oct. 27, 1897	7.3	6		Middle knot.	2,200			
38	Nov. 3, 1897	...	6½		Middle knot.	2,020			
39	Nov. 9, 1897	...	6		Middle knot.	2,000			

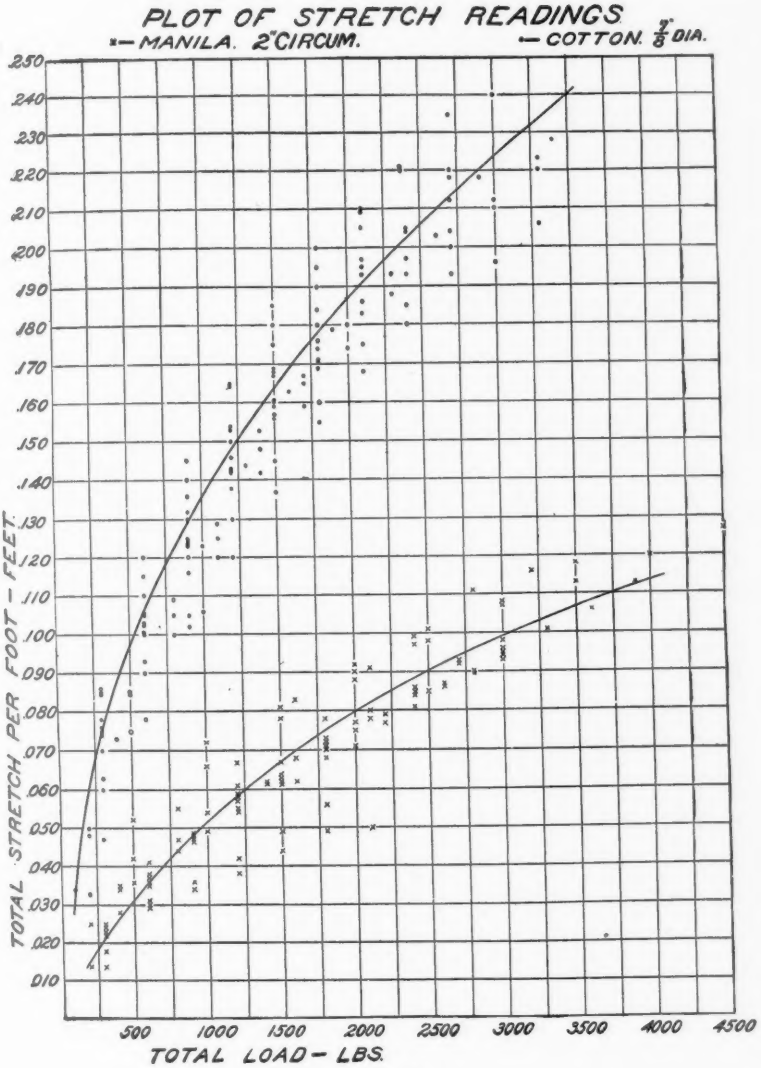

PLOT OF STRETCH READINGS
×— MANILA. 2" CIRCUM.
— COTTON. 7/8 DIA.
TOTAL STRETCH PER FOOT — FEET.
.250
.240
.230
.220
.210
.200
.190
.180
.170
.160
.150
.140
.130
.120
.110
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
500
1000
1500
2000
2500
3000
3500
4000
4500
TOTAL LOAD — LBS.

FIG. 6.

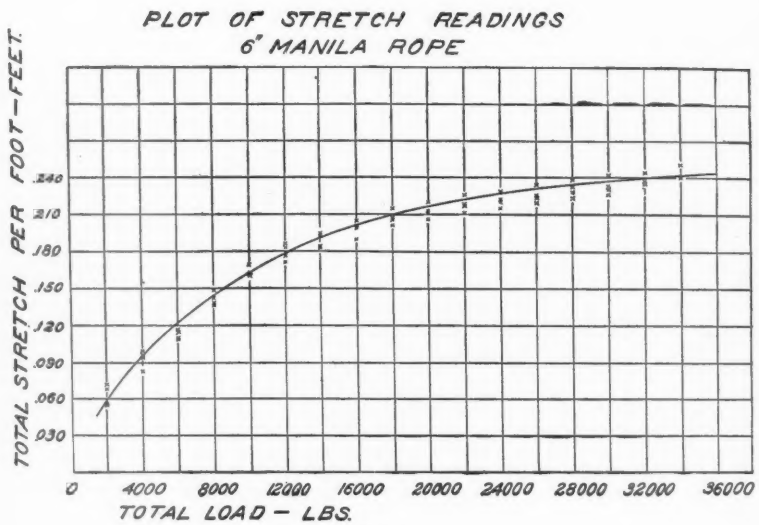

PLOT OF STRETCH READINGS
6" MANILA ROPE
TOTAL STRETCH PER FOOT—FEET.
.240
.210
.180
.150
.120
.090
.060
.030
0
4000
8000
12000
16000
20000
24000
28000
32000
36000
TOTAL LOAD — LBS.

FIG. 7.

TESTS ON MANILA ROPE. (6″ circumference.)

Number of test.	Date.	Maximum Load.	Location of Break.	Kind of Knots or Splices used.
1	Nov. 4, 1898 . .	35,700	Scale end splice.	Eye splices over iron eyes.
2	Nov. 4, 1898 . .	33,100	Power end splice.	
3	Nov. 4, 1898 . .	34,800	3″ from scale end splice.	
4	Nov. 4, 1898 . .	33,400	Scale end splice.	

These tests were made in the Emery Testing Machine. The splices were wet, and the central portion of the rope dry. The following is a plot of the scale readings upon the stretch apparatus for ordinates and loads for abscissæ. The rope consisted of 4 strands of 51 lines per strand, twisted over a core made up of 3 strands, 7 lines per strand, making a total of 225 lines.

Cement Tests.

The tests on cement in tension were made on briquettes of 1 square inch cross section, and in compression on 2″ cubes. A description of the method of making these tests may be found in the *Technology Quarterly*, Vol. IX, Nos. 2, 3, 1896. The sand used in making the sand tests was ground white quartz fine enough to pass through a sieve with 20 meshes per linear inch.

PORTLAND CEMENT. — NEAT CEMENT. (Tension.)

Date of Test.	Brand.	Per cent. of Water Used in Mixing.	Time of Set.	Breaking Strength.
Nov. 20, 1897	Atlas.	20	2 days.	434
Nov. 20, 1897	"	20	2 days.	420
Nov. 5, 1897	"	20	4 days.	666
Nov. 5, 1897	"	20	4 days.	720
Nov. 5, 1897	"	20	4 days.	746
Nov. 3, 1897	"	20	5 days.	686
Nov. 3, 1897	"	20	5 days.	728
Oct. 18, 1897	"	23	7 days.	724
Oct. 20, 1897	"	23	7 days.	708
Oct. 20, 1897	"	23	7 days.	715
Oct. 22, 1897	"	20	7 days.	708
Oct. 22, 1897	"	20	7 days.	718
Oct. 22, 1897	"	20	7 days.	740
Oct. 22, 1897	"	20	7 days.	818
Oct. 25, 1897	"	20	7 days.	700
Nov. 3, 1897	"	20	7 days.	750
Nov. 3, 1897	"	20	7 days.	784
Nov. 3, 1897	"	20	7 days.	816
Nov. 19, 1897	"	20	7 days.	724
Nov. 19, 1897	"	20	7 days.	838
Nov. 22, 1897	"	20	7 days.	795
Nov. 22, 1897	"	20	7 days.	832

PORTLAND CEMENT. — NEAT CEMENT. (Tension.) — *Concluded.*

Date of Test.	Brand.	Per cent. of Water Used in Mixing.	Time of Set.	Breaking Strength.
Nov. 24, 1897	Atlas.	20	7 days.	749
Nov. 24, 1897	"	20	7 days.	780
Nov. 24, 1897	"	20	7 days.	845
Dec. 9, 1897	"	20	7 days.	786
Dec. 11, 1897	"	20	7 days.	786
Nov. 10, 1897	"	20	9 days.	802
Nov. 10, 1897	"	20	9 days.	812
Nov. 10, 1897	"	20	9 days.	790
Dec. 10, 1897	"	20	9 days.	910
Nov 8, 1897	"	19.5	12 days.	900
Nov. 8, 1897	"	19.5	12 days.	916
Nov. 8, 1897	"	19.5	12 days.	960
Nov. 8, 1897	"	19.5	12 days.	964
Nov. 8, 1897	"	19.5	12 days.	965
Dec. 31, 1898	Alsen.	27	1 day.	290
Dec. 31, 1898	"	27	1 day.	290
Dec. 31, 1898	"	27	1 day.	296
Dec. 31, 1898	"	27	1 day.	330
Dec. 31, 1898	"	27	1 day.	336
Dec. 31, 1898	"	27	1 day.	348
Dec. 31, 1898	"	27	1 day.	348
Nov. 11, 1898	"	27	2 days.	530
Nov. 11, 1898	"	27	2 days.	556
Nov. 11, 1898	"	27	2 days.	514
Dec. 16, 1898	"	27	2 days.	509
Dec. 16, 1898	"	27	2 days.	520
Dec. 16, 1898	"	27	2 days.	640
Jan. 6, 1899	"	27	2 days.	545
Jan. 11, 1899	"	27	2 days.	520
Dec. 21, 1898	"	27	5 days.	544
Dec. 21, 1898	"	27	5 days.	580
Dec. 21, 1898	"	27	5 days.	580
Dec. 21, 1898	"	27	5 days.	610
Dec. 21, 1898	"	27	5 days.	652
Dec. 21, 1898	"	27	5 days.	668
Nov. 14, 1898	"	27	7 days.	678
Nov. 14, 1898	"	27	7 days.	690
Nov. 14, 1898	"	27	7 days.	780
Jan. 9, 1899	"	27	7 days.	770
Jan. 9, 1899	"	27	7 days.	790
Jan. 9, 1899	"	27	7 days.	790
Nov. 16, 1898	"	27	14 days.	770
Nov. 16, 1898	"	27	14 days.	780
Nov. 16, 1898	"	27	14 days.	844
Dec. 12, 1898	"	27	14 days.	832
Jan. 11, 1899	"	27	1 mo.	836
Jan. 11, 1899	"	27	1 mo.	914
Mar. 16, 1899	Saylor's.	24	2 days.	426
Mar. 16, 1899	"	24	2 days.	440
Mar. 16, 1899	"	24	2 days.	498
Mar. 16, 1899	"	24	2 days.	498
Mar. 16, 1899	"	24	7 days.	722
Dec. 20, 1898	"	24	7 days.	700
Dec. 20, 1898	"	24	7 days.	720
Dec. 20, 1898	"	24	7 days.	820
Dec. 20, 1898	"	24	7 days.	838
Dec. 20, 1898	"	24	7 days.	870
Mar. 13, 1899	"	24	7 days.	702
Mar. 13, 1899	"	24	7 days.	724
Mar. 13, 1899	"	24	7 days.	752
Mar. 14, 1899	"	24	7 days.	706
Mar. 14, 1899	"	24	7 days.	824
June 12, 1899	"	24	3 mos.	975
June 12, 1899	"	24	3 mos.	1,065
June 12, 1899	"	24	3 mos.	1,000
June 12, 1899	"	24	3 mos.	1,085
June 12 1899	"	24	3 mos.	1,050
June 12, 1899	"	24	3 mos.	930

PORTLAND CEMENT.—NEAT CEMENT. (Compression.)

Date of Test.	Brand.	Per cent. of Water Used in Mixing.	Time of Set.	Breaking Strength.
Nov. 20, 1897	Atlas.	20	2 days.	11,950
Nov. 20, 1897	"	20	2 days.	12,910
Nov. 20, 1897	"	20	2 days.	13,750
Nov. 5, 1897	"	20	4 days.	19,740
Nov. 5, 1897	"	20	4 days.	20,180
Nov. 5, 1897	"	20	4 days.	20,830
Nov. 5, 1897	"	20	4 days.	22,000
Nov. 3, 1897	"	20	5 days.	20,000
Nov. 3, 1897	"	20	5 days.	21,030
Nov. 3, 1897	"	20	5 days.	21,150
Nov. 3, 1897	"	20	5 days.	21,160
Nov. 24, 1897	"	20	6 days.	22,550
Oct. 22, 1897	"	20	7 days.	22,990
Oct. 22, 1897	"	20	7 days.	23,670
Oct. 22, 1897	"	20	7 days.	24,000
Oct. 22, 1897	"	20	7 days.	24,000
Oct. 22, 1897	"	20	7 days.	25,000
Oct. 22, 1897	"	20	7 days.	25,140
Oct. 22, 1897	"	20	7 days.	23,120
Nov. 10, 1897	"	20	9 days.	24,820
Nov. 10, 1897	"	20	9 days.	24,850
Nov. 10, 1897	"	20	9 days.	26,000
Dec. 10, 1897	"	20	9 days.	25,450
Dec. 10, 1897	"	20	9 days.	25,800
Nov 10, 1897	"	20	1 mo.	30,600
Nov. 10, 1897	"	20	1 mo.	30,700
Nov. 24, 1897	"	20	1 mo.	34,000
Nov. 24, 1897	"	20	1 mo.	36,000
Oct. 29, 1898	"	20	1 year.	59,400
Oct. 29, 1898	"	20	1 year.	53,550
Oct. 29, 1898	"	20	1 year.	59,400
Oct. 29, 1898	"	20	1 year.	62,150
Oct. 29, 1898	"	20	1 year.	63,900
Oct. 29, 1898	"	20	1 year.	67,050
Oct. 29, 1898	"	20	1 year.	67,550
Dec. 31, 1898	Alsen.	20	1 day.	7,100
Dec. 31, 1898	"	20	1 day.	7,840
Dec. 31, 1898	"	20	1 day.	7,880
Dec. 31, 1898	"	20	1 day.	8,180
Dec. 31, 1898	"	27	1 day.	8,400
Dec. 31, 1898	"	27	1 day.	8,900
Nov. 11, 1898	"	27	2 days.	13,150
Nov. 11, 1898	"	27	2 days.	13,140
Nov. 11, 1898	"	27	2 days.	13,140
Nov. 11, 1898	"	27	2 days.	14,350
Nov. 11, 1898	"	27	2 days.	14,600
Dec. 16, 1898	"	27	2 days.	13,380
Dec. 16, 1898	"	27	2 days.	13,560
Dec. 16, 1898	"	27	2 days.	14,000
Dec. 16, 1898	"	27	2 days.	14,330

PORTLAND CEMENT. — NEAT CEMENT. (Compression.) — *Concluded.*

Date of Test.	Brand.	Per cent. of Water Used in Mixing.	Time of Set.	Breaking Strength.
Dec. 16, 1898	Alsen.	27	2 days.	14,850
Dec. 16, 1898	"	27	2 days.	14,910
Dec. 16, 1898	"	27	2 days.	15,230
Jan. 6, 1899	"	27	2 days.	13,400
Jan. 6, 1899	"	27	2 days.	13,400
Dec. 21, 1898	"	27	5 days.	14,000
Dec. 21, 1898	"	27	5 days.	15,030
Dec. 21, 1898	"	27	5 days.	15,380
Dec. 21, 1898	"	27	5 days.	16,000
Dec. 21, 1898	"	27	5 days.	16,600
Dec. 21, 1898	"	27	5 days.	17,340
Nov. 12, 1898	"	27	5 days.	17,370
Nov. 14, 1898	"	27	7 days.	18,780
Nov. 14, 1898	"	27	7 days.	18,000
Nov. 14, 1898	"	27	7 days.	18,400
Nov. 14, 1898	"	27	7 days.	19,000
Jan. 9, 1899	"	27	7 days.	19,880
Jan. 9, 1899	"	27	7 days.	18,150
Jan. 9, 1899	"	27	7 days.	21,400
Nov. 16, 1898	"	27	7 days.	21,800
Nov. 16, 1898	"	27	14 days.	21,390
Nov. 16, 1898	"	27	14 days.	22,000
Jan. 11, 1899	"	27	14 days.	22,500
Jan. 11, 1899	"	27	1 mo.	22,600
Jan. 11, 1899	"	27	1 mo.	23,550
Mar. 1, 1899	"	27	1 mo.	25,400
Mar. 1, 1899	"	27	3 mos.	26,070
June 6, 1899	"	27	3 mos.	23,730
June 6, 1899	"	27	6 mos.	36,280
Mar. 16, 1899	Saylor's.	24	6 mos.	46,400
Mar. 16, 1899	"	24	2 days.	12,050
Mar. 16, 1899	"	24	2 days.	12,210
Mar. 16, 1899	"	24	2 days.	12,300
Mar. 16, 1899	"	24	2 days.	12,350
Mar. 16, 1899	"	24	2 days.	13,600
Mar. 16, 1899	"	24	7 days.	23,560
Mar. 16, 1899	"	24	7 days.	24,000
Mar. 16, 1899	"	24	7 days.	24,180
Mar. 16, 1899	"	24	7 days.	26,000
Mar. 16, 1899	"	24	7 days.	26,180
Dec. 20, 1898	"	24	7 days.	23,030
Mar. 13, 1899	"	24	7 days.	25,890
Mar. 13, 1899	"	24	7 days.	26,230
Mar. 25, 1899	"	24	14 days.	28,920
Mar. 25, 1899	"	24	14 days.	27,800
Mar. 25, 1899	"	24	14 days.	29,210
June 6, 1899	"	24	3 mos.	33,030
June 6, 1899	"	24	3 mos.	33,870
June 6, 1899	"	24	3 mos.	36,450
June 6, 1899	"	24	3 mos.	33,100

PORTLAND CEMENT. — SAND TESTS. (Tension.)

Date of Test.	Brand.	Parts Sand to one Part Cement.	Per cent. of Water Used in Mixing.	Time of Set.	Breaking Strength.
Nov. 20, 1897 . .	Atlas.	2	12	2 days.	80
Nov. 20, 1897 . .	"	2	12	2 days.	84
Nov. 20, 1897 . .	"	2	12	2 days.	86
Dec. 15, 1897 . .	"	2	12	2 days.	94
Nov. 24, 1897 . .	"	2	12	6 days.	230
Dec. 9, 1897 . .	"	2	12	7 days.	260
Dec. 13, 1897 . .	"	2	12	7 days.	278
Dec. 13, 1897 . .	"	2	12	7 days.	279
Dec. 13, 1897 . .	"	2	12	7 days.	290
Dec. 13, 1897 . .	"	2	12	7 days.	320
Dec. 13, 1897 . .	"	2	12	7 days.	290
Nov. 16, 1898 . .	"	2	12	1 year.	469
Dec. 23, 1898 . .	"	2	12	1 year.	360
Dec. 23, 1898 . .	"	2	12	1 year.	360
Dec. 23, 1898 . .	"	2	12	1 year.	398
Dec. 5, 1898 . .	Alsen.	3	12	3 days.	109
Dec. 5, 1898 . .	"	3	12	3 days.	121
Dec. 12, 1898 . .	"	3	12	3 days.	101
Dec. 12, 1898 . .	"	3	12	3 days.	106
Dec. 12, 1898 . .	"	3	12	3 days.	111
Dec. 12, 1898 . .	"	3	12	3 days.	118
Dec. 19, 1898 . .	"	3	12	7 days.	170
Dec. 19, 1898 . .	"	3	12	7 days.	181
Dec. 19, 1898 . .	"	3	12	7 days.	182
Dec. 19, 1868 . .	"	3	12	7 days.	191
Dec. 19, 1898 . .	"	3	12	7 days.	212
Dec. 19, 1898 . .	"	3	12	7 days.	245
Dec. 2, 1898 . .	"	3	12	14 days.	250
Dec. 2, 1898 . .	"	3	12	14 days.	253
Dec. 2, 1898 . .	"	3	12	14 days.	255
Dec. 2, 1898 . .	"	3	12	14 days.	284
Jan. 9, 1899 . .	"	3	12	1 mo.	258
Jan. 9, 1899 . .	"	3	12	1 mo.	260
Jan. 9, 1899 . .	"	3	12	1 mo.	320
Mar. 23, 1899 . .	Saylor's.	3	12	2 days.	68
Mar. 23, 1899 . .	"	3	12	2 days.	72
Mar. 25, 1899 . .	"	3	12	7 days.	146
Mar. 27, 1899 . .	"	3	12	7 days.	143
Mar. 27, 1899 . .	"	3	12	7 days.	138
Mar. 29, 1899 . .	"	3	12	7 days.	135
Mar. 29, 1099 . .	"	3	12	7 days	134
Mar. 30, 1899 . .	"	3	12	12 days.	130
Mar. 30, 1899 . .	"	3	12	12 days.	138
Mar. 30, 1899 . .	"	3	12	12 days.	160
June 12, 1899 . .	"	3	12	2 mos.	205
June 12, 1899 . .	"	3	12	2 mos.	210
June 12, 1899 . .	"	3	12	2 mos.	225
June 12, 1899 . .	"	3	12	2 mos.	245

PORTLAND CEMENT. — SAND TESTS. (Compression.)

Date of Test.	Brand.	Parts Sand to one Part Cement.	Per cent. of Water Used in Mixing.	Time of Set.	Breaking Strength.
Nov. 20, 1897 . .	Atlas.	2	12	2 days.	2,550
Nov. 20, 1897 . .	"	2	12	2 days.	2,700
Nov. 20, 1897 . .	"	2	12	2 days.	3,190
Nov. 19, 1897 . .	"	2	12	7 days.	6,240
Nov. 19, 1897 . .	"	2	12	7 days.	7,150
Nov. 24, 1897 . .	"	2	12	7 days.	6,030
Nov. 24, 1897 . .	"	2	12	7 days.	6,030
Nov. 24, 1897 . .	"	2	12	7 days.	7,080
Nov. 24, 1897 . .	"	2	12	7 days.	7,120
Dec. 10, 1897 . .	"	2	12	7 days.	6,290
Dec. 13, 1897 . .	"	2	12	7 days.	6,820
Dec. 13, 1897 . .	"	2	12	7 days.	7,600
Dec 13, 1897 . .	"	2	12	7 days.	7,700
Dec. 13, 1897 . .	"	2	12	7 days.	7,700
Dec. 13, 1897 . .	"	2	12	7 days.	8,150
Nov. 16, 1898 . .	"	2	12	1 year.	17,250
Dec. 20, 1898 . .	"	2	12	1 year.	16,790
Dec. 20, 1898 . .	"	2	12	1 year.	17,270
Dec. 23, 1898 . .	"	2	12	1 year.	22,000
Dec. 23, 1898 . .	"	2	12	1 year.	19,220
Dec. 23, 1898 . .	"	2	12	1 year.	17,700
Dec. 23, 1898 . .	"	2	12	1 year.	20,750
Dec. 23, 1893 . .	"	2	12	1 year.	22,000
Dec. 5, 1898 . .	Alsen.	3	12	3 days.	2,620
Dec. 5, 1898 . .	"	3	12	3 days.	3,030
Dec. 5, 1898 . .	"	3	12	3 days.	3,250
Dec. 5, 1898 . .	"	3	12	3 days.	3,158
Dec. 12, 1898 . .	"	3	12	3 days.	2,600
Dec. 12, 1898 . .	"	3	12	3 days.	2,640
Dec. 12, 1898 . .	"	3	12	3 days.	2,810
Dec. 19. 1898 . .	"	3	12	7 days.	4,350
Dec. 19, 1898 . .	"	3	12	7 days.	4,520
Dec. 19, 1898 . .	"	3	12	7 days.	4,760
Dec. 19, 1898 . .	"	3	12	7 days.	4,230
Dec. 19, 1898 . .	"	3	12	7 days.	4,750
Dec. 19, 1898 . .	"	3	12	7 days.	4,900
Dec. 2, 1898 . .	"	3	12	14 days.	4,470
Dec. 2, 1898 . .	"	3	12	14 days.	4,490
Dec. 2, 1898 . .	"	3	12	14 days.	4,780
Mar. 23, 1899 . .	Saylor's.	3	12	2 days.	1,540
Mar. 23, 1899 . .	"	3	12	2 days.	1,580
Mar. 23, 1899 . .	"	3	12	2 days.	1,690
Mar. 23, 1899 . .	"	3	12	2 days.	1,910
Mar. 25, 1899 . .	"	3	12	7 days.	3,820
Mar. 27, 1899 . .	"	3	12	7 days.	4,200
Mar. 27, 1899 . .	"	3	12	7 days.	4,320
Mar. 27, 1899 . .	"	3	12	7 days.	4,290
Mar. 27, 1899 . .	"	3	12	7 days.	4,580
Mar. 29, 1899 . .	"	3	12	7 days.	3,880
Mar. 29, 1899 . .	"	3	12	7 days.	4,180
June 12, 1899 . .	"	3	12	2 mos.	4,500
June 12, 1899 . .	"	3	12	2 mos.	4,700
June 12, 1899 . .	"	3	12	2 mos.	5,150

Tests on Building Brick.

This set of tests was undertaken to find the crushing strength of common building bricks when tested separately, and was made on a 300,000 pounds Emery testing machine.

Three series of tests were made: the first on Dover River hard and soft burned bricks; the second on Central New York hard, medium, and soft burned bricks; and the third on some hard burned bricks which were stored in the basement of the Engineering Laboratory at the Institute. In all these tests the bearing surfaces were set in neat Portland cement which was smoothed off to a plane surface, to provide an even bearing for the bricks against the platforms of the testing machine.

In the first and second series of tests the pressure was applied to the broad surfaces of the bricks, and the tables which follow give the area of the cross section, or the bearing area, the maximum load on the brick, and the maximum load per square inch.

The third series was made in order to compare the breaking load per square inch, obtained by applying the pressure to the broad surfaces, with that obtained by applying the pressure to the edge of the bricks. The tables give the results in the same form as for the preceding series.

In nearly all the tests the amount of water which the bricks would absorb was ascertained and is given in the last column of the tables. The bricks were weighed when dry and then immersed in water until no further gain in weight was obtained, and then weighed again. The amount of water absorbed is given in per cent. of the weight of the dry brick. Time enough was allowed for the cement to set and for the bricks to dry out thoroughly before the tests were made.

DOVER RIVER. (Soft Burned.)

Number of Test.	Area of Cross Section. (Sq. in.)	Maximum Load. (Lbs.)	Maximum Load (Lbs. per sq. in.)	Amount of Water Absorbed. (Per cent.)
1	28.4	135,000	4,750	13.2
2	28.5	175,000	6,140	14.2
3	29.4	140,000	4,760	....
4	28.5	146,000	5,140	14.7
5	29.4	132,000	4,490	13.1
6	28.0	148,000	5,290	....
7	29.0	163,000	5,620	....
8	29.0	173,000	5,970	....
9	29.0	151,000	5,210	14.8
10	29.0	138,000	4,760	15.7
11	28.0	178,000	6,360	13.1
12	28.0	170,000	6,070	12.2
13	29.0	119,000	4,100	16.6
14	29.0	132,000	4,550	14.9
15	28.5	144,000	5,050	....
16	30.5	124,000	4,070	17.0
17	29.5	138,000	4,680	12.2
18	28.1	183,000	6,510	13.9
19	29.0	136,000	4,690	18.6
20	27.8	240,000	8,630	12.3
21	28.5	208,000	7,300	12.3
22	28.8	180,000	6,250	12.5
23	27.1	220,000	8,120	11.6
24	28.5	169,000	5,930	15.7
25	29.0	126,000	4,340	12.6
26	29.0	142,000	4,900	13.0
27	29.5	158,000	5,360	14.0
28	29.0	139,000	4,790	....
29	28.1	173,000	6,150	....
30	28.5	188,000	6,600	14.4
31	29.5	166,000	5,630	13.3
32	29.7	193,000	6,500	14.9
33	29.0	178,000	6,140	....
34	28.5	151,000	5,300	....
35	28.1	131,000	4,650	....
36	30.7	159,000	5,180	....
37	28.1	174,000	6,200	....
38	28.5	112,000	3,930	....
Average			5,530	14.0
Maximum			8,630	18.6
Minimum			3,930	11.6

DOVER RIVER. (Hard Burned.)

Number of Test.	Area of Cross Section. (Sq. in.)	Maximum Load. (Lbs.)	Maximum Load. (Lbs. per sq. in.)	Amount of Water Absorbed. (Per cent.)
1	26.2	206,000	7,860	6.0
2	25.8	240,000	9,300	5.4
3	27.6	189,000	6,850	7.6
4	27.6	231,000	8,370	6.5
5	27.3	199,000	7,290	6.2
6	26.2	167,000	6,370	6.8
7	28.1	210,000	7,470	6.6
8	26.9	181,000	6,730	6.7
9	27.8	203,000	7,300	8.9
10	26.4	230,000	8,710	5.8
11	27.1	288,000	10,630	8.5
12	26.6	207,000	7,770	10.1
13	26.9	183,000	6,800	6.5
14	27.1	220,000	8,120	6.2
15	27.1	221,000	8,150	6.4
16	25.7	245,000	9,530	4.7
17	25 6	280,000	10,940	...
19	26.4	262,000	9,920	6.0
20	26 6	260,000	9,770	7.6
21	27.1	202,000	7,520	7.0
22	26.6	186,000	6,990	7.1
24	26.4	219,000	8,310	5.8
25	29.0	170,000	5,850	9.9
26	26.2	231,000	8,800	5.2
27	27.1	177,000	6,520	6.8
28	28.4	191,000	6,730	9.0
29	26.6	197,000	7,400	6.7
30	27.1	204,000	7,530	6.8
32	28.8	254,000	8,820	6.8
33	24.9	234,000	9,400	...
34	27.1	239,000	8,820	7.8
35	28.8	220,000	7,640	9.0
36	28.0	231,000	8,250	7.8
Average			8,070	7.0
Maximum			10,940	10.1
Minimum			5,850	4.7

CENTRAL NEW YORK. (Soft Burned.)

Number of Test.	Area of Cross Section. (Sq. in.)	Maximum Load. (Lbs.)	Maximum Load. (Lbs. per sq. in.)	Amount of Water Absorbed. (Per cent.)
1	34.3	63,000	1,840	19.6
2	33.5	61,000	1,820	20.9
3	33.5	75,000	2,240	19.3
4	34.0	60,000	1,800	20.0
5	33.3	69,000	2,070	18.7
6	34.5	77,000	2,230	18.9
7	33.5	59,000	1,760	21.7
8	34.3	47,000	1,370	21.5
9	33.0	81,000	2,460	17.8
10	33.0	83,000	2,510	18.0
11	33.3	78,000	2,350	18.9
12	33.3	60,000	1,800	21.1
13	33.5	76,000	2,270	19.5
14	33.0	77,000	2,330	19.1
15	33.3	69,000	2,070	21.9
16	33.3	61,000	1,830	21.0
17	33.5	73,000	2,180	18.9
18	33.3	64,000	1,920	20.5
19	33.0	75,000	2,270	19.8
20	33.0	80,000	2,420	20.7
21	33.3	58,000	1,740	20.7
22	33.3	71,000	2,130	19.8
23	33.3	76,000	2,280	19.6
24	31.0	91,000	2,930	18.7
25	33.3	84,000	2,520	18.2
26	33.5	83,000	2,490	19.2
27	33.5	72,000	2,150	20.5
28	33.0	76,000	2,300	19.1
29	33.0	77,000	2,320	19.9
30	32.4	63,000	1,640	21.9
31	33.0	71,000	2,150	22.0
32	32.5	77,000	2,380	18.7
33	33.7	75,000	2,220	20.3
34	33.5	97,000	2,900	19.2
35	33.5	73,000	2,100	22.2
36	33.7	103,000	3,060	19.8
Average			2,190	19.9
Maximum			3,060	22.0
Minimum			1,370	17.8

CENTRAL NEW YORK. (Medium.)

Number of Test.	Area of Cross Section. (Sq. in.)	Maximum Load. (Lbs.)	Maximum Load. (Lbs. per sq. in.)	Amount of Water Absorbed. (Per cent.)
1	32.2	108,000	3,360	17.6
2	31.7	104,000	3,280	16.6
3	32.2	110,000	3,420	16.9
4	31.7	126,000	3,970	16.7
5	32.2	109,000	3,390	23.4
6	31.7	105,000	3,310	17.7
7	31.5	120,000	3,810	17.3
8	31.5	88,000	2,800	20.4
9	31.7	129,000	4,080	16.7
10	32.9	127,900	3,860	18.4
11	31.5	118,000	3,750	18.0
12	31.2	99,000	3,170	20.8
13	31.5	104,000	3,300	18.1
14	32.2	122,000	3,780	18.3
15	32.0	105,000	3,280	18.0
16	31.2	121,000	3,880	18.3
17	31.2	94,000	3,000	18.5
18	31.5	87,000	2,080	20.8
19	32.5	129,000	3,970	18.7
20	32.5	123,000	3,790	19.0
21	31.7	121,000	3,820	19.6
22	31.0	85,000	2,740	20.9
23	31.2	135,000	4,330	18.2
24	32.2	116,000	3,600	19.2
25	31.5	126,000	4,000	18.1
26	31.2	100,000	3,210	20.9
27	32.0	133,000	4,160	18.4
28	31.7	157,000	4,950	18.5
29	31.5	119,000	3,780	19.0
30	32.0	116,000	3,620	18.6
31	31.7	102,000	3,220	18.7
32	32.7	123,000	3,760	18.2
33	31.7	129,000	4,070	18.1
34	31.0	115,000	3,710	16.9
Average			3,600	18.6
Maximum			4,950	23.4
Minimum			2,080	16.6

CENTRAL NEW YORK. (Hard Burned.)

Number of Test.	Area of Cross Section. (Sq. in.)	Maximum Load. (Lbs.)	Maximum Load. (Lbs. per sq. in.)	Amount of Water Absorbed. (Per cent.)
2	31.0	120,000	3,870	16.7
3	30.2	100,000	3,310	11.7
4	29.5	146,000	4,950	13.6
5	29.5	194,000	6,580	10.9
6	29.5	198,000	6,710	11.0
7	31.7	135,000	4,260	13.9
8	31.4	160,000	5,100	12.0
9	30.0	193,000	6,430	10.4
10	32.5	160,000	4,920	14.2
11	31.5	227,000	7,210	9.4
12	31.2	275,000	8,810	8.3
13	31.0	149,000	4,810	15.0
14	31.2	202,000	6,470	10.1
15	30.4	162,000	4,170	15.1
16	31.2	130,000	5,330	16.4
17	28.3	132,000	4,670	15.0
18	28.8	135,000	4,690	12.3
19	29.3	171,000	5,840	10.2
20	28.3	173,000	6,110	12.8
21	29.1	166,000	5,700	11.8
22	28.6	174,000	6,080	12.5
23	31.2	190,000	6,090	12.5
24	30.7	187,000	6,090	12.5
26	30.5	212,000	6,950	13.0
27	28.3	123,000	4,340	10.3
29	28.4	164,000	5,780	11.3
30	31.0	134,000	4,320	....
31	31.4	130,000	4,140	....
32	29.1	162,000	5,570	10.2
33	31.8	123,000	3,870	14.1
34	32.5	132,000	4,060	14.4
35	30.8	139,000	4,510	11.9
36	32.5	168,000	5,170	13.4
Average			5,360	12.5
Maximum			8,810	16.7
Minimum			3,310	8.3

HARD BURNED BRICKS STORED IN BASEMENT OF LABORATORY.

Number of Test.	Area of Cross Section. (Sq. in.)	Maximum Load. (Lbs.)	Maximum Load. (Lbs. per sq. in.)	Amount of Water Absorbed. (Per cent.)
2	30.5	220,000	7,210	11.0
3	30.0	221,000	7,370	12.0
4	30.7	204,000	6,650	12.0
5	31.2	205,000	6,570	11.0
6	30.7	263,000	8,560	8.8
7	31.2	250,000	8,010	10.7
9	30.7	300,000	9,770	10.1
10	30.7	210,000	6,840	12.3
12	31.5	249,000	7,900	10.7
13	31.2	258,000	8,270	10.6
14	30.2	223,000	7,380	12.9
15	29.2	272,000	9,320	7.6
16	29.3	274,000	9,350	7.6
Average			7,940	10.6
Maximum			9,770	12.9
Minimum			6,570	7.6
17	18.3	98,000	5,350	13.2
18	17.6	180,000	10,230	6.2
19	18.1	109,000	6,020	11.0
20	18.6	91,000	4,890	12.8
21	18.9	98,000	5,180	12.6
23	18.8	98,000	5,210	10.9
24	19.6	108,000	5,510	12.9
25	19.1	106,000	5,560	12.1
26	18.6	163,000	8,760	9.9
27	19.6	75,000	3 830	12.8
28	19.4	116,000	5,980	11.0
29	17.9	131,000	7,320	18.7
30	18.7	86,000	4,600	10.1
31	18.0	171,000	9,500	7.4
32	18.0	152,000	8,440	9.4
Average			6,430	11.4
Maximum			10,230	18.7
Minimum			3,830	6.2

NOTE. — In tests Nos. 2–16 the pressure was applied to the broad surface, and in tests Nos. 17–32 the pressure was applied to the edge of the bricks.

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[1] Published in *Technology Quarterly*, Vols. VII to XII (1894 to 1899). The Roman numerals in the index refer to the volume of the *Quarterly*. The numerals in parentheses indicate the part of the *Tests*.

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